CREEKS, BROOKS AND RIVERS

IN

ROCKLAND COUNTY, NEW YORK

and

Their Relation to Planning For the Future

By

Gordon R. Ayer and F. H. Pauszek

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Prepared in cooperation with

the Board of Supervisors, Rockland County, New York

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ABSTRACT

The use of water has increased steadily in Rockland County. From 1900 to 1960, the population increased from 38,300 to 136,800. By 1980 it is estimated the population will be 338,000. About 50.7 mgd (million gallons per day) would be required to satisfy the water needs of so large a population. Industry is also a big user of water; in 1961 over 8 mgd was used by industry in the County. Recreation is demanding its share of water. All these needs point to possible water problems.

Of these, perhaps the problem of water supply comes first - sufficient water for domestic use, industry, agriculture and recreation. Pollution abatement, drainage, and flood control are some of the other water problems.

Surface water plays an important part in the solution of present-day water problems in Rockland County. Records collected during the past two years indicate that the surface-water situation in the County is favorable. During the 1961 water year, the average flow of surface water was 1.18 million gallons per day per square mile of drainage area or about 210 million gallons per day from the total land surface of 173 square miles in the County. However, this supply is highly variable from month to month and year to year and additional storage will be needed to make a larger part of the streamflow available for use.

What is the chemical quality of surface water in Rockland County? Based on mineral content, most surface water appears to be satisfactory for many uses - public water supply, industrial, agricultural and recreational. Mineral content constitutes a large part of the dissolved-solids content of most waters. In most samples the dissolved-solids content was moderate; in the Ramapo River basin it was very low, less than 50 ppm (parts per million). Water in streams in the County ranged from soft to hard. For some sensitive industrial processes and even for public water supply, the dissolved solids and hardness would have to be reduced. In some waters, iron and manganese could present a problem, particularly during low flow; concentrations of about 0.3 ppm or more would cause stains and deposit.

The sediment load and water temperature of some streams in Rockland County were also determined. Sediment is a problem of moderate magnitude especially in the Hackensack River and Pascack Brook. Temperature of surface waters fluctuate seasonally and responded readily to changes in air temperatures.

These are the facts in brief. More detailed information will be presented in the material that follows. Water problems may arise. However, they can be anticipated and, with judicious water management, their impact can be reduced. To this end, knowledge of the quantity and quality of water resources is necessary. To furnish such knowledge is the purpose of this report.

INTRODUCTION

The phrase, "coming events cast their shadows before them," is a very apt one, although it may or may not be true in any given situation. Be that as it may, even now the shadow of water problems is apparent in parts of the United States and perhaps in Rockland County too. In the United States, the estimated per capita use of water has increased from 50 gpd (gallons per day) in 1900 to about 150 gpd at the present time. Using these figures and multiplying by the evergrowing population (76 million in 1900 and 179 million in 1960), the problem of water supply begins to take shape. MacKichan and Kammerer (1961) report that about 21,000 mgd were withdrawn from public water supplies alone in 1960, an increase of 4,000 mgd since 1955.

In Rockland County, the population increased from 38,300 in 1900 to 136,800 in 1960. According to the Rockland County Data Book (1961), the estimate of population for 1980 is 338,000, an increase of 147 percent over that of 1960 (fig. 1). About 50.7 mgd would be required to satisfy the water needs of so large a population as compared with 21.9 mgd used in 1961.

Industrial needs for water are increasing. In 1947 there were 120 industrial plants in the County; in 1958 there were 158; and in 1961 there were 169 plants. According to Wilson (1962) more than 8 mgd of water were used by industry in Rockland County in 1961. What the industrial need for water will be in 1980 has not been predicted. However, there is vacant space for expansion in the County and further industrial growth can be expected in succeeding decades (fig. 2).

The use of water for recreational purposes is also increasing. Fishing used to be and is still a favorite sport. Boating is also becoming a widely favored sport. This requires larger bodies of water for maneuverability. Where natural lakes are available there is no problem. In other areas, development of large ponds or impoundment of streams to form man-made lakes will be needed to take care of this recreational need. Swimming is another popular sport. This demand for water can be met in part by swimming pools. But, swimming pools do not replace the "old swimming hole" in its natural setting. So there are and will be multiple demands on the available water resources in the County and recreation will be demanding its rightful share.

In Rockland County several thousand acres of land including ponds and lakes are set aside for recreational purposes. However, much of this land is owned by New York State and is operated as the Palisades Interstate Park. For this reason it attracts large numbers of visitors from outside the County leaving little Park area for Rockland County residents. At the same time this imposes a tremendous strain on the water resources and gives rise to the question of what effect further expansion of the park facilities may have on the County's water supply.

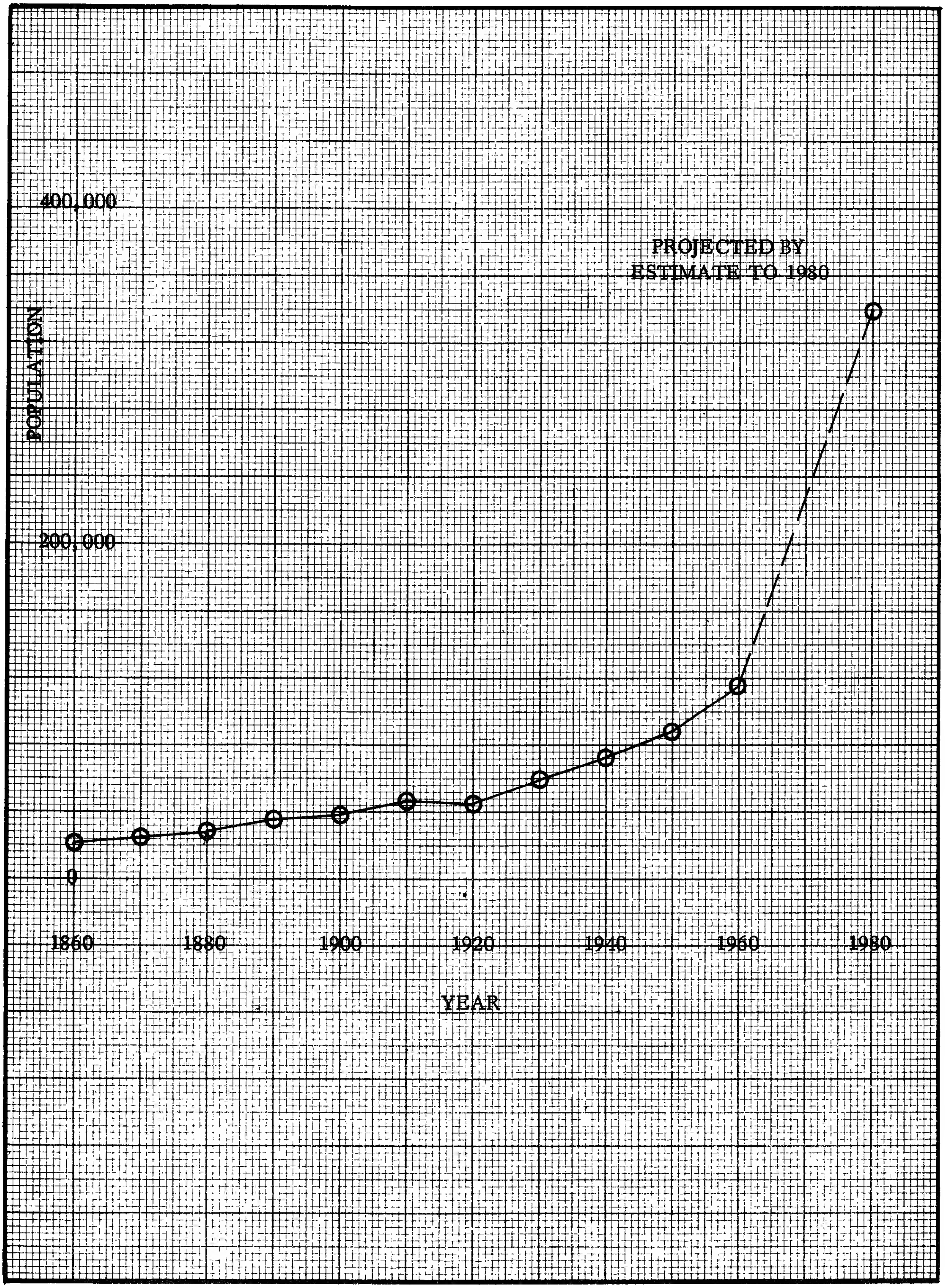

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Figure 1.--Population trend in Rockland County, 1860-1980
(Source; Rockland County Data Book, 1961)

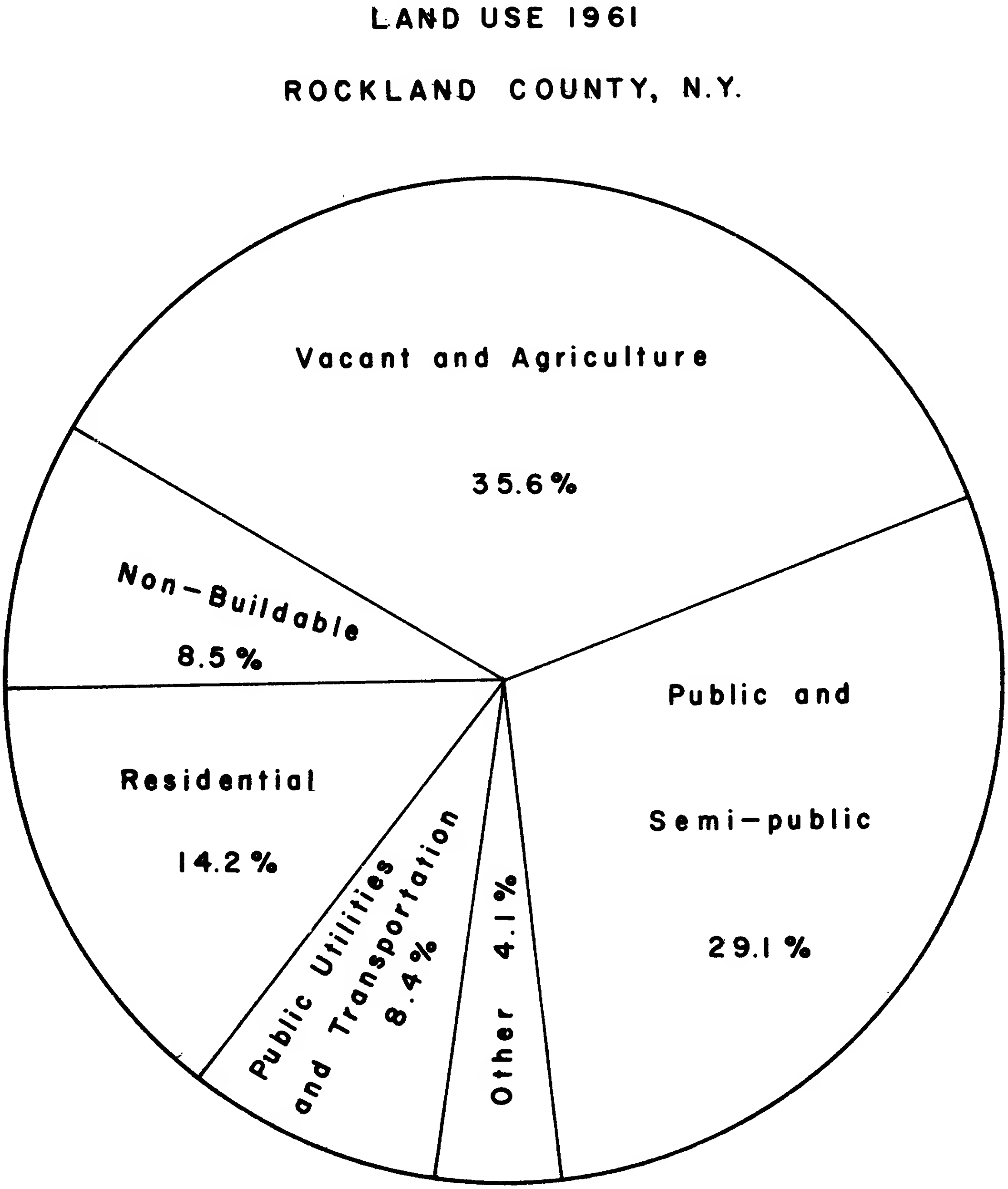


Figure 2. - Land use in Rockland County, 1961.

Source; Rockland County Data Book, 1961

Because of these situations, coming events indeed point to possible water problems. Of these, perhaps the problem of water supply is of primary concern -- sufficient water for domestic use, industry, agriculture and recreation, now and in the future. Stream pollution usually follows in the wake of expanding population and industrial growth and impairs the available water supply. As urbanization takes place drainage problems arise. Floods are a natural problem but no less important. These are some of the problems that deserve further examination.

Where does Rockland County get its water? Precipitation is the initial source. The average annual amount of precipitation in the County is approximately 48 inches. However, there are years when the total precipitation falls below the average, and other years when the total is considerably above average (fig. 3). During the water year 1960 precipitation was below average for six months although the total for the year was considerably above normal (fig. 4). During water year 1961 precipitation was below normal for seven months and the annual total slightly below the long-term average.

Usually the total precipitation for the year is fairly uniformly distributed in Rockland County. However, during the past twenty-two years, totals of less than one inch have been recorded during the months of October, December, June and September. Totals of more than 13.5 inches have been recorded in October, July and August (fig. 5). The lowest monthly average has been that of February, 3.20 inches, and the highest, 5.40 inches for July.

The total water used in the County, estimated at approximately 21.9 million gallons per day in 1961, is obtained about equally from ground water and surface water sources. The County Planning Board estimated that 9.3 mgd of ground water was supplied to 60,100 users through public water distribution systems. An additional 1.5 mgd, from privately owned wells, served about 28,000 people. The remaining water used in the County, 11.1 mgd, was obtained from surface water sources. Thus it is evident that surface water now plays an important part in the water supply picture, and it is likely that it will be used to an even greater extent in the future, as water supply problems develop.

The pollution potential of an area may be evaluated by considering what proportion of the population is served by an adequate sewage system and by a safe water supply. Natural pollution is to be expected. This usually consists of foreign matter carried into streams by overland runoff-decayed vegetation, animal excreta, eroded soil and leached chemical substances. They may or may not impair the utility of water. Usually this is not as serious as man-made pollution. Man-made pollution includes domestic and industrial wastes, sediment from disturbed soil cover, and thermal wastes that raise the temperature of water.

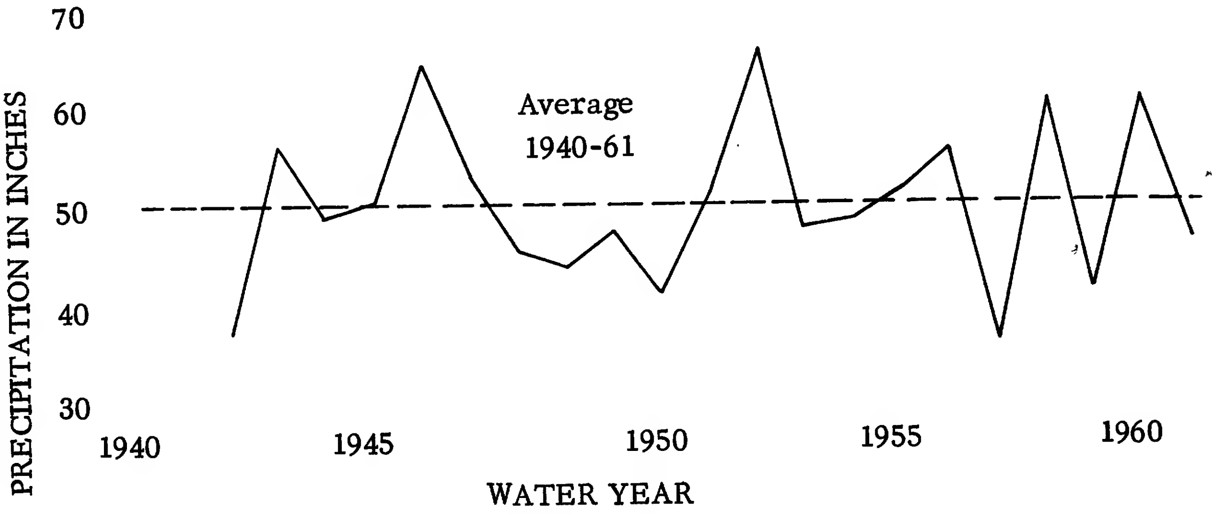


Figure 3. - Annual Precipitation, Letchworth Village, 1940-61.

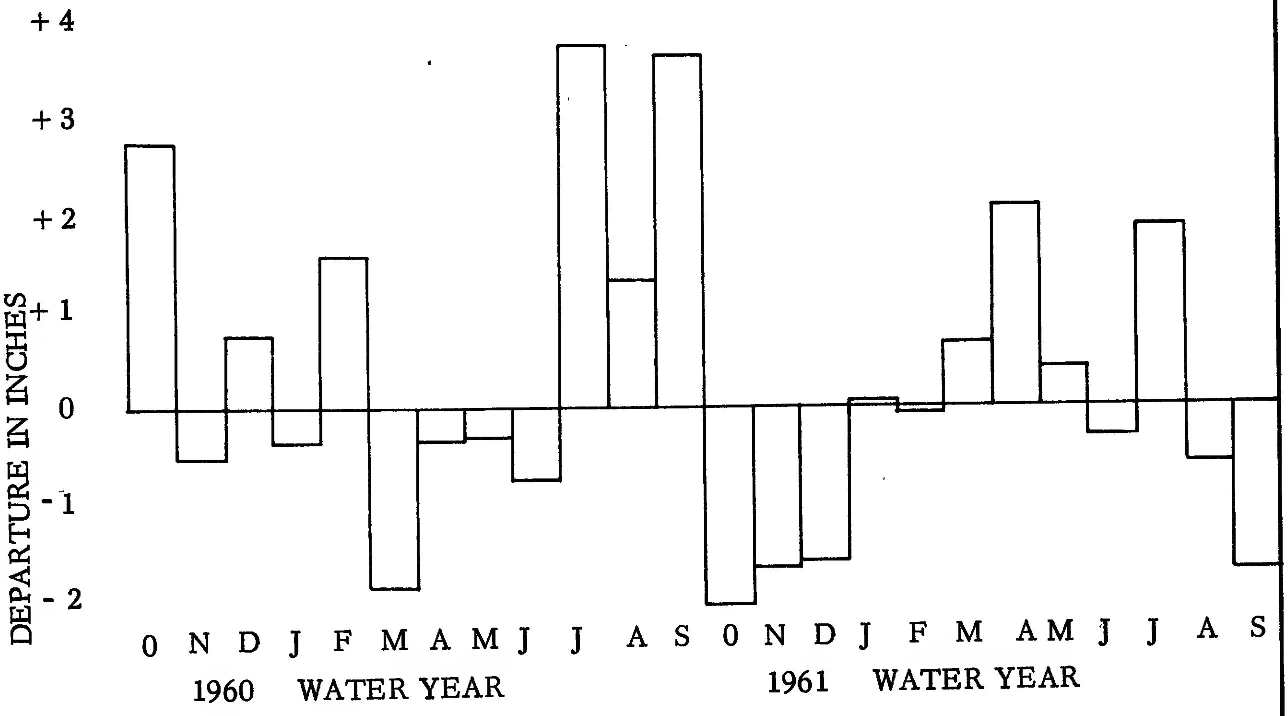


Figure 4. - Departure of monthly precipitation in 1960 and 1961 at Letchworth Village from the average of 1940-61.

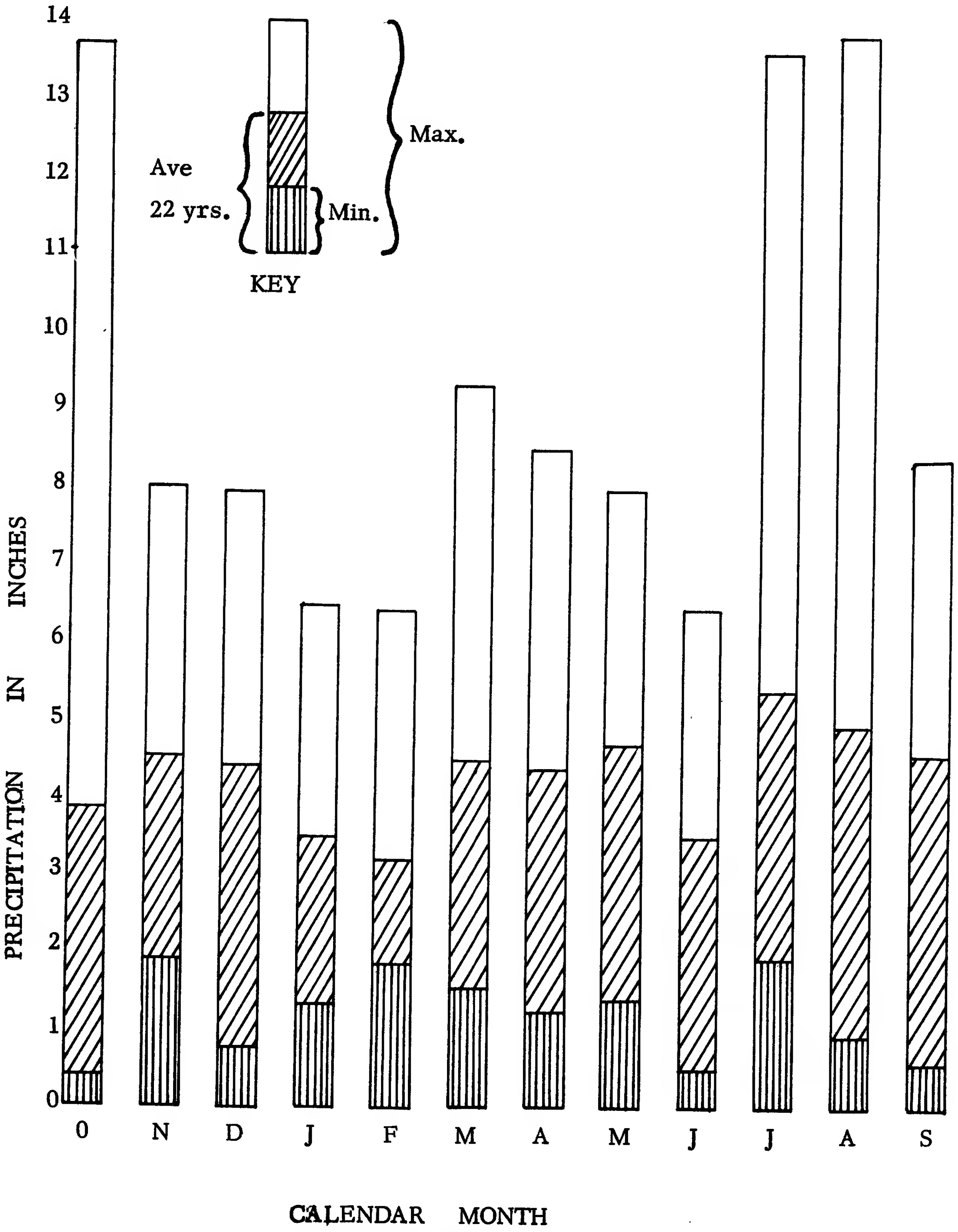


Figure 5. - Maximum, average, and minimum monthly precipitation at Letchworth Village, 1940-61

In Rockland County only about 42 percent of the population is served by public sewage systems. Domestic wastes from the remaining population are discharged directly into streams or septic tanks. In turn, wastes from septic tanks may contaminate ground-water or surface-water supplies. Detergents rapidly are becoming a problem.

The extent of pollution in the Sparkill, Ramapo and Mahwah drainage basins has been studied and reported by the Water Pollution Control Section, New York State Health Department (1951, 1953). However, the investigation was conducted about 10 years ago. Whether the condition has improved or worsened since that time is not known.

With respect to urbanization, every area faces problems of adequate drainage for the runoff from precipitation. Rockland County is no exception. According to Nussbaumer, Clark and Velzy (1960), the large increase in both population and development in the County in the past decade, together with the prospect of continued development, has clearly indicated the need for orderly and effective planning of drainage facilities.

As urbanization progresses, drainage problems become more complex. Under natural conditions, streams in a drainage basin establish a rather well-defined regimen of slope, channel shape, ponded areas, and a combination of pools and rapids. The sediment load in streams will vary with terrain features, soil characteristics, and vegetal cover. The chemical quality of water in the streams will reflect the geology of the area, ground-water inflow, and dilution from surface runoff. Under natural conditions, these basin characteristics usually adjust themselves to a condition of equilibrium.

As man encroaches upon nature through construction of bridges, culverts, embankments, retaining walls, and channel realignment, streams attempt to ward off these modifications. Backwater builds up above constrictions. Aggradation of the stream takes place in some reaches and degradation in others. Where paved areas and buildings replace vegetated land, the rate and percent of direct runoff from a given storm increase rapidly. As the rate of flowing water increases, the entire regimen of the basin changes. Urbanization gives rise to another water problem, that of flood damages.

In regard to floods in Rockland County, only a small amount of historical data are available. Major floods are known to have occurred in the Ramapo and Hackensack River basins in 1903, 1936 and 1955.

Heavy rainfall and failure of several small dams upstream from Suffern were responsible for a flood of the Ramapo River in October 1903. During this flood, a peak discharge of 12,400 cfs (cubic feet per second) was reported near Mahwah, New Jersey. This was equivalent to 105 cfs per square mile of drainage area above the location.

At the same location, a peak discharge of 7,710 cfs was recorded in March 1936. This is equivalent to 75 cfs per square mile. Another high peak of 10,900 cfs (92 cfs per square mile) occurred during the hurricane flood of October 1955. Upstream at Sloatsburg, a peak of 98 cfs per square mile was recorded in 1955. It was still higher at a point one mile south of Tuxedo Park where a peak flow equivalent to 103 cfs per square mile was measured. During the periods 1903-06, 1922-61, no flood in the upper Ramapo basin has exceeded either the 1903 or 1955 peaks.

The only recording gage on the Hackensack River above Oradell Reservoir with more than five years of record is at Rivervale, New Jersey; for this station a record, since 1941, is available. From 1941 to 1961, two sizeable peak discharges occurred, one in April 1951, when a peak of 1,350 cfs was recorded, and the maximum of record, 1450 cfs, that occurred in October 1955. Based on a drainage area of 58 square miles, these peaks are equivalent to 23 and 25 cfs per square mile, respectively.

The difference in the peak rate of runoff of the Ramapo and Hackensack Rivers for the 1955 flood indicates the relative flood potential of these two streams. Of the two, the Ramapo has the greater potential.

Historical flood data on small streams in Rockland County are not available. But information obtained during the last two years will be reported in subsequent sections.

These are the possible problems; possible, because they can be anticipated and, with judicious water management, steps can be taken to reduce their impact.

But, before decisions can be made, knowledge about the quantity and quality of water resources has to be at hand. Perlmutter (1959) reported on the geology and ground-water resources of Rockland County. The purpose of this report is to present and interpret information on streamflow characteristics, and chemical and physical quality including sediment of surface waters in Rockland County. The data presented and analyzed are those collected during the past two and one half years at 17 continuous stream-gaging stations, 5 partial-record stations, and 20 miscellaneous sites. Sampling of the quality of water was done at 22 sites.

Tables of monthly and annual stream flow at a number of gaging sites throughout the County are included in the report. Daily discharge figures for water years prior to 1961 can be found in U. S. Geological Survey Water Supply Papers, Part 1B. The 1961 water-year figures are available in the publication "Surface Water Records of New York, 1961," prepared by the Geological Survey in cooperation with the State of New York and other agencies.

Acknowledgments are extended to the County Board of Supervisors and Rockland County Planning Board for the initiation and support of the project in cooperation with the U. S. Geological Survey. The New York State Department of Commerce encouraged the project as a further step in the development of Rockland County. William A. Washington of the Surface Water Branch, U. S. Geological Survey, was resident Engineer.

Gaging Station, Mahwah River near Suffern, N.Y.

Ramapo River at Sloatsburg, N.Y.

The Setting

Rockland County encompasses that portion of the land on the west side of the Hudson River in the southern extremity of New York State, adjacent to northern New Jersey. It has the general shape of an isosceles triangle with its base extending approximately 26 miles along the west shoreline of the Hudson River (fig. 6). The maximum east-west dimension is about 19 miles. The northwesterly leg of the triangle is 18 miles long and forms the boundary between Rockland and Orange Counties. The southwesterly leg extends about 20 miles and forms the boundary between Rockland County, and Bergen and Passaic Counties in New Jersey. The total land-surface area is approximately 173 square miles.

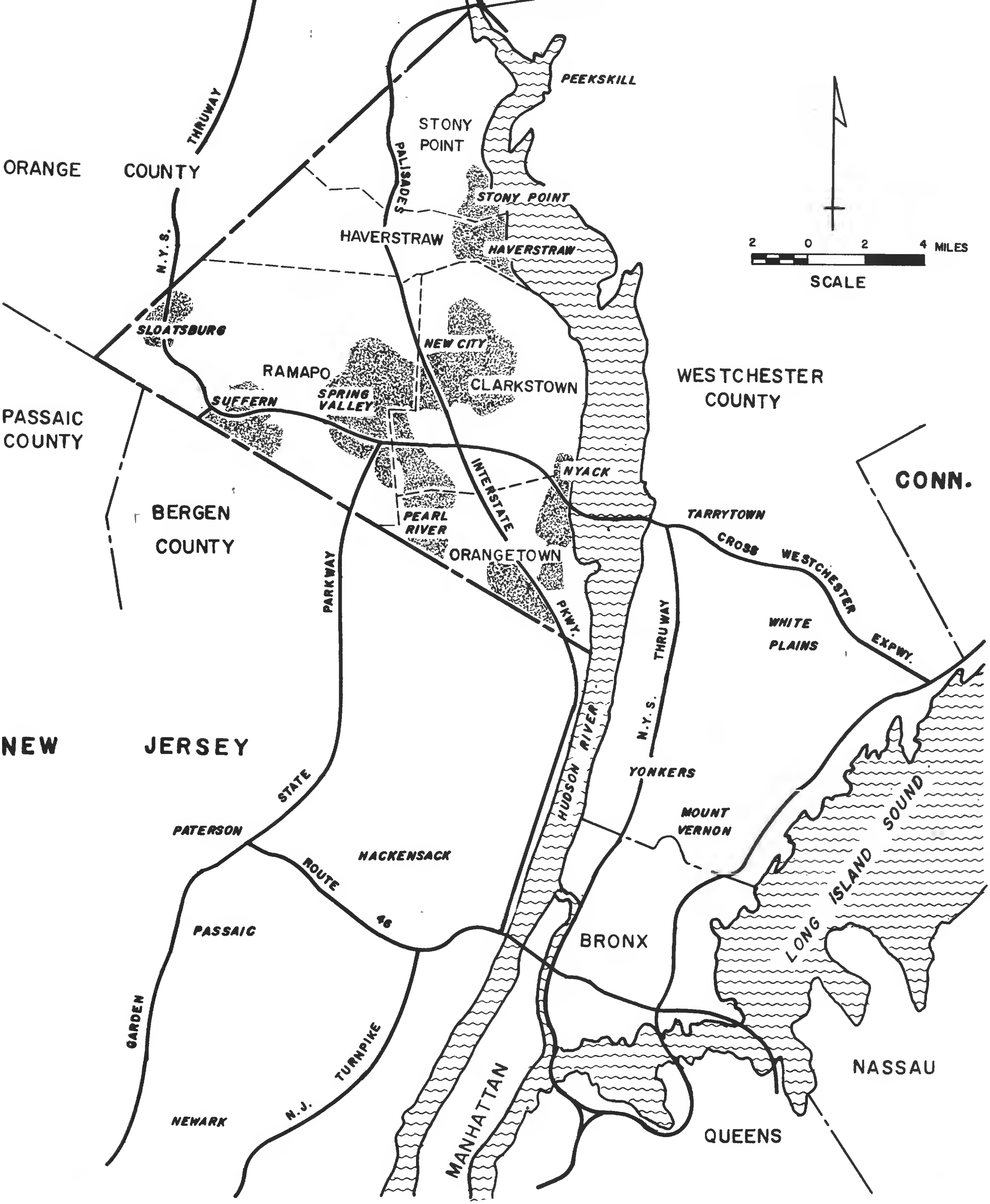
Topographically, Rockland County is unique. In an area of less than 200 square miles, mountain tops at more than 1,200 feet in elevation lie only a few miles from tidewater in the Hudson River. The Palisades and South Mountain on the east and the Ramapo Mountains on the northwest divide the County into two relatively distinct regions.

West of the Palisades and south of South Mountain is a rolling terrain characterized by gentle ridges and hills of moderate relief. North of the Mountain, the terrain is more rugged and the sharply defined relief at the northern end of the Ramapo Mountains is interrupted by gentle, sloping valleys and flat areas.

The rolling terrain of the lower part of the County terminates on the west along the Mahwah River and in the background the sharp rugged relief of the Ramapo Mountains dominates the land surface.

Sedimentary rocks underlie the eastern two-thirds of Rockland County with crystalline rocks underlying most of the remaining area. Deposits of till cover most of the bedrock surface. Stratified drift composed of sand, gravel, silt and clay overlies the deposits of till in many stream valleys. The stratified drift is generally less than 100 feet thick but in the buried channel of the Hudson River, it may be as much as 600 feet thick.

This is the setting. Now, what are the creeks, brooks and rivers that flow across this setting called Rockland County? How much water can be obtained from them on a day-to-day basis, monthly, annually, and under what conditions? Is the water soft? Does it contain iron and manganese? These are some of the questions that will be answered in the following pages.



REGIONAL POSITION OF ROCKLAND COUNTY

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CEDAR POND BROOK BASIN

Lake Tiorati Brook

Lake Tiorati Brook rises at Lake Tiorati in the Palisades Interstate Park, Orange County, at an elevation of 1,030 feet and flows in a southeast direction into the Hudson River. At Cedar Flats, about 3.5 miles downstream from its source, Lake Tiorati Brook is joined by a small tributary draining Upper and Lower Pound swamps. The combined drainage of the two streams at this location is 10.5 square miles.

Although this is a small drainage area, runoff was sufficient to maintain flow in Lake Tiorati Brook even during the summer months. The minimum discharge (1959-61) was 0.6 cfs (table 1). Streamflow was in excess of 2 cfs, 97.5 percent of the time in 1960 and 90 percent in 1961 (fig. 7). Further, a flow equal to or in excess of 10 cfs occurred 78 percent of the time in 1960 and 68 percent of the time in 1961.

A comparison of the flow of Lake Tiorati Brook for the 2-year period of record has been made with discharge records of long standing for streams in southern New York and Northern New Jersey. Using this procedure, it is sometimes possible to estimate the position and shape of the long-term duration curve for a stream with a short-term record. The broken line in figure 7 shows what may be expected for Lake Tiorati Brook over a long period of time. Comparison of the three curves shows that 1960 and 1961 were relatively wet years with streamflow somewhat in excess of that to be expected on the average below the 50 percent duration point. This was because precipitation in Rockland County for the 1960 water year was third highest since 1940, and the 1961 rainfall was so distributed that no extremely dry period occurred.

Referring to figure 7, the relatively steep slope of the upper end of the curve indicates that this stream has a moderately rapid runoff during a storm. The steepness of the lower end indicates poor low-flow capabilities. These factors are important in determining the best use of a stream. Steep upper portions of the duration curve suggest high flood-producing potential while steep lower portions indicate poor low-water yield for recreation, water supply, and waste disposal. It appears that Lake Tiorati Brook is capable of maintaining some flow even during relatively low-flow periods.

During periods of precipitation, Lake Tiorati Brook responds readily. On August 26, 1961, 3.62 inches of rain were recorded at the Cedar Flats gage between 1 and 2 p. m. The night before, during a two-hour period (10-12 p. m.) an additional 1.06 inches had been recorded. Lake Tiorati Brook responded to the early afternoon rain within 15 minutes and rose three feet within an hour. This rise in stage was equivalent to an increase from 13 to nearly 1,000 cfs. The peak stage and discharge occurred within 15 minutes after the rain ended and the Brook receded rapidly - one foot in 1 1/2 hours and a total of two feet in 11 hours. Figure 8 shows the response of Lake Tiorati Brook to this precipitation and the subsequent recession. According to the U. S. Weather Bureau (1961) a rain storm of this intensity can be expected only once in more than 100 years.

Table 1. - Summary of Streamflow, Lake Tiorati Brook at Cedar Flats, 1959-61

Location.--Lat 41°14'26", long 74°01'29", on left bank downstream from Gate Hill Road highway bridge, on State Highway 210, at Cedar Flats, 0.1 mile downstream from tributary from Upper Pound Swamp.

Drainage area.--10.5 sq mi.

Records available.--October 1959 to December 1961.

Gage.--Water stage recorder. Altitude of gage is 215 ft (from topographic map).

Extremes.--1959-60: Maximum discharge during water year, 714 cfs Aug. 19 (gage height, 4.79 ft); minimum, 1.0 cfs July 27.

1960-61: Maximum discharge during water year, 983 cfs Aug. 26 (gage height, 5.19 ft); minimum, 0.6 cfs Sept. 30.

Remarks.--Records good. Precipitation record at site since May 1960.

Monthly and yearly mean discharge, in cubic feet per second

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The Year
1960	21.0	30.3	43.5	32.2	45.2	23.2	46.3	18.7	8.44	14.8	32.8	32.8	29.0
1961	7.37	12.3	14.7	15.8	48.0	61.3	61.0	39.9	14.6	6.28	12.7	4.82	24.7

Monthly and yearly runoff, in inches

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The Year
1960	2.30	3.22	4.77	3.53	4.65	2.55	4.92	2.05	0.90	1.62	3.60	3.48	37.59
1961	0.81	1.30	1.61	1.73	4.76	6.73	6.48	4.38	1.55	0.69	1.40	0.51	31.95

Peak discharge (base, 250 cfs)

Date	Time	Gage Height (ft)	Discharge (cfs)	Date	Time	Gage Height (ft)	Discharge (cfs)
10-24-59	2:00 pm	3.76	262	9-12-60	3:00 pm	4.45	518
1-3-60	10-11 am	3.84	287	2-25-61	11:15 pm	4.55	572
2-11-60	10:30 pm	3.78	268	4-16-61	3:45 pm	4.01	324
7-30-60	1:00 pm	4.13	387	8-26-61	2:00 pm	5.19	983
8-19-60	11:00 am	4.79	714				

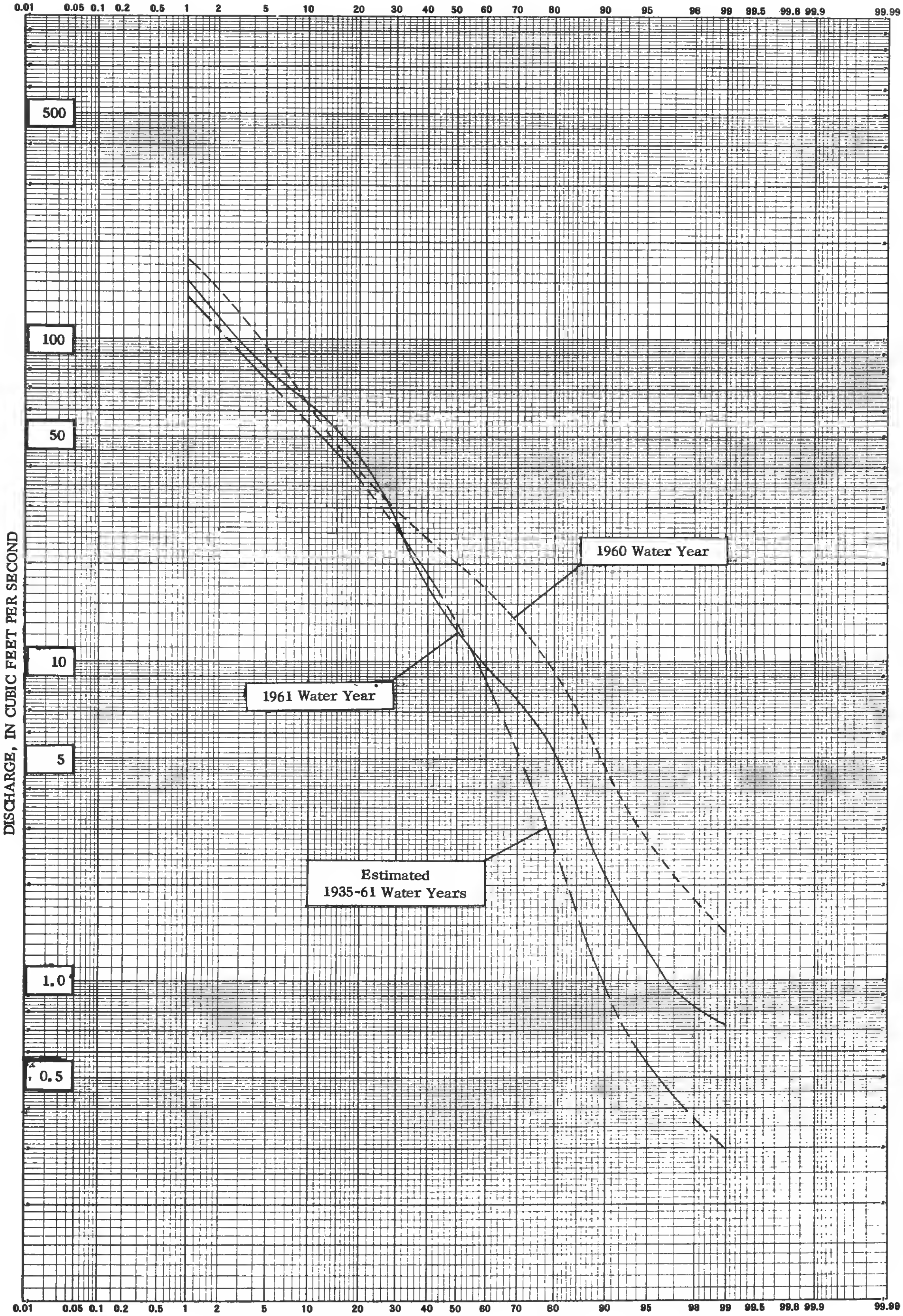

Figure 7.--Duration curves of daily flow, Lake Tiorati Brook at Cedar Flats, N. Y.

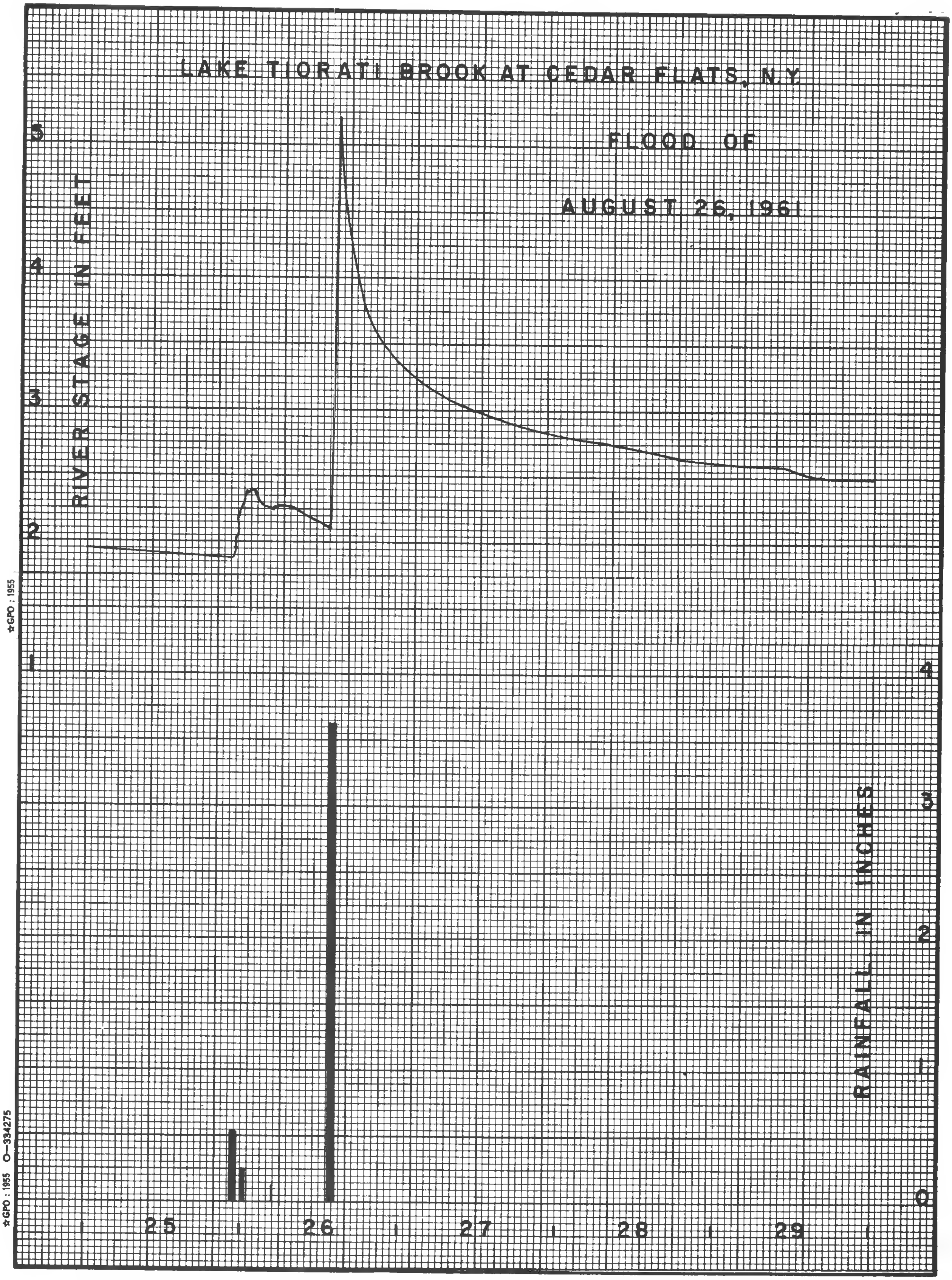

Figure 8.--Precipitation and river stage, Aug. 25-29, 1961, Lake Tiorati Brook at Cedar Flats, N. Y.

On September 20-21, 1961, a storm of less magnitude resulted in a total rainfall at Cedar Flats of 1.25 in. spread over an 18-hour period. During this storm the stream responded almost immediately and the peak stage occurred as soon as the rain stopped. The stage rose slightly more than three-quarters of a foot (1.96 to 2.73 ft) representing an increase in flow from about 1 to nearly 100 cfs. About seven days were required for a return to pre-storm levels.

On November 29, 1960, 1.24 inches of rain over a 6-hour period produced a rise in stage of about one foot. This was followed by a more gradual recession. The gradual recession is attributed to a lower rate of use of water by vegetation during the fall and winter months.

To determine the relative yield for selected parts of Lake Tiorati Brook basin, measurements of flow under base-flow conditions have been made (table 50). Comparison of a set of measurements for a single day serves as a basis of evaluating the relative contribution made by the several sub-basins.

If conditions warrant, flow in the stream can be augmented by withdrawal from Lake Tiorati through two 4-inch siphon pipes at the dam on the lake. These siphons are maintained by the New York Water Service Division, Utilities and Industries Corporation. According to the Palisades Interstate Park Commission, no use was made of the siphons during the 1959-61 period.

How about the chemical quality of water from Lake Tiorati Brook at Cedar Flats? It was excellent. The mineral content was low. One sample of water contained 40 ppm of dissolved solids (table 2). The specific conductance (a measure of mineral content) of other water samples indicated that the dissolved solids content was equally low or only slightly higher. The highest computed concentration of dissolved solids (based on specific conductance) was about 50 ppm. Further, water from Lake Tiorati Brook was very soft. Hardness ranged from 16 to 36 ppm in 4 water samples. Calcium and bicarbonate were the principal constituents. Concentrations of other constituents were very low and would not affect the utility of water from Lake Tiorati Brook for most purposes.

Cedar Pond Brook

Cedar Pond Brook is actually a continuation of Lake Tiorati Brook. It is the name given to that reach of the stream starting below the bridge on Highway 210 at Cedar Flats and continuing to tide water at Stony Point, a distance of about three miles. Two tributaries enter about 1 1/4 miles downstream from Cedar Flats upstream from a small pond that serves as a reservoir for public water supply diverted by the New York Water Service Division, Utilities and Industries Corporation. Below the reservoir the stream flows an easterly course to the Hudson River, flowing in a valley with fairly steep sides, through the village of Stony Point. No major tributaries enter through this reach, but storm-water runoff flows into the stream from the village streets during rainy periods.

Table 2. - Chemical analyses, Lake Tiorati Brook at Cedar Flats

(parts per million)

Date of collection	9/1/59	12/3/59	7/13/60	8/31/61
Silica (SiO_2)		7.7		
Iron (Fe)		.03		
Manganese (Mn)		.04		
Calcium (Ca)		5.2		
Magnesium (Mg)		.6		
Sodium (Na)		2.2		
Potassium (K)		.6		
Bicarbonate (HCO_3)	14	7	24	19
Sulfate (SO_4)		13		
Chloride (Cl)		3.2		
Fluoride (F)		.1		
Nitrate (NO_3)		.3		
Dissolved solids				
Residue on evaporation at 180°C		40		
Hardness as $CaCO_3$	24	16	36	29
Specific conductance (micromhos at 25°C)	61	60	88	85
pH	7.2	6.2	6.9	6.7
Color		4		
Temperature, °F	72	41	68	72

Streamflow in Cedar Pond Brook fluctuated over a wide range during 1960-61 from a minimum of 0.2 cfs to a maximum of 830 cfs (table 3). This gives the gross picture but does not reveal the potential usefulness of Cedar Pond Brook. A statistical analysis shows that, during the 1961 water year, 95 percent of the time the discharge from Cedar Pond Brook at Stony Point was 3.5 cfs or more (fig. 9). The flows were above 88 cfs 10 percent of the time. These statistics are based on a one-year record and should be used with caution in predicting future occurrences.

According to water company records, the average diversion from Cedar Pond Brook during 1959-61 was 1.25 cfs varying from 1.1 cfs in January 1961 to 1.5 cfs in June 1960 and September 1961. In addition to this diversion for public water supply an average of 1.95 cfs was diverted for industrial cooling but this was returned to the stream.

When two or more stream-gaging stations are in operation on a single stream it is frequently of interest to compare the records of flow to help in evaluating the contribution from various parts of the basin (table 37). A similar study can be made to evaluate the effects of man-made regulation. Table 4 shows the results of a study of the Cedar Pond Brook basin wherein the effects of diversion of flow for water-supply purposes below the Lake Tiorati Brook gage are evident. Note the decrease in unit runoff from the upstream to the downstream site and the low unit yield from the intervening area. If the Cedar Pond Brook record were increased by the amount of diversion, 0.07 cubic foot per second per square mile, the monthly unit rates of flow would be nearer the same but the upstream rate would still be the greater.

It is anticipated that a considerable amount of housing development will take place in the Cedar Pond Brook basin below Cedar Flats during the next few years. This will result in higher rates of runoff from precipitation. Consequently, the flood potential will be increased in the lower reaches of the stream.

On the basis of mineral content, the chemical quality of Cedar Pond Brook at Stony Point is good (the sanitary quality has not been determined). However, seasonal fluctuations were noted. Dissolved-solids content, in four water samples, ranged from an estimated 52 to 121 ppm (based on specific conductance measurements). The higher concentrations were measured in water samples collected during summer months. Such seasonal changes in concentrations are common in surface waters. Streamflow during summer months is usually very low and is sustained by ground-water inflow. Because ground water usually contains more dissolved solids than runoff entirely from surface sources, the mineral content of the stream also is increased. The low hardness of water from Cedar Pond Brook contributed to its good quality. The hardness was as low as 30 ppm, a very soft water. Even the higher value of 87 ppm, determined for a water sample collected July 13, 1960, would be considered as moderate hardness.

Table 3. - Summary of Streamflow, Cedar Pond Brook at Stony Point, 1959-61

Location.--Lat 41°13'36", long 73°59'04", on left bank 50 ft upstream from bridge on Lowland Hill Road, 1,200 ft downstream from U. S. Highway 9-W, at Stony Point, 0.9 mile downstream from water-supply reservoir, and 1 1/2 miles upstream from mouth.

Drainage area.--17.3 sq mi.

Records available.--November 1959 to December 1961.

Gage.--Water-stage recorder. Altitude of gage is 5 ft (from topographic map). Prior to Dec. 16, 1959, staff gage at same site and datum.

Extremes.--1959-60: Maximum discharge during period November to September, 685 cfs Aug. 19 (gage height, 4.58 ft); minimum, 0.2 cfs July 26; minimum daily, 1.0 cfs July 26.

1960-61: Maximum discharge during water year, 830 cfs Aug. 26 (gage height, 4.95 ft); minimum, 0.7 cfs Aug. 20; minimum daily, 0.8 cfs Aug. 18-20.

Remarks.--Records good. Diversion from upstream reservoir about 1 cfs, for water supply.

Monthly and yearly mean discharge, in cubic feet per second

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The Year
1960	-	43.2	63.7	50.2	71.2	34.2	67.7	34.4	11.5	20.5	42.2	47.5	-
1961	13.7	18.6	20.7	25.8	71.3	87.1	79.6	52.9	18.8	9.61	18.4	9.80	35.3

Monthly and yearly runoff, in inches

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The Year
1960	-	2.79	4.24	3.34	4.44	2.28	4.37	2.29	0.74	1.37	2.82	3.06	-
1961	0.91	1.20	1.38	1.72	4.29	5.81	5.14	3.53	1.21	0.64	1.23	0.63	27.69

Peak discharge (base, 250 cfs)

Date	Time	Gage Height (ft)	Discharge (cfs)	Date	Time	Gage Height (ft)	Discharge (cfs)
1-3-60	11:30 am	3.49	362	9-12-60	5:00 pm	4.13	535
2-11-60	11:00 am	3.35	332	2-26-61	1:00 am	4.36	609
4-5-60	3:00 pm	3.15	290	4-16-61	5:30 pm	3.68	407
7-30-60	3:00 pm	3.94	479	5-28-61	1:00 am	3.00	260
8-19-60	12:30 pm	4.58	685	8-26-61	4:15 pm	4.95	830

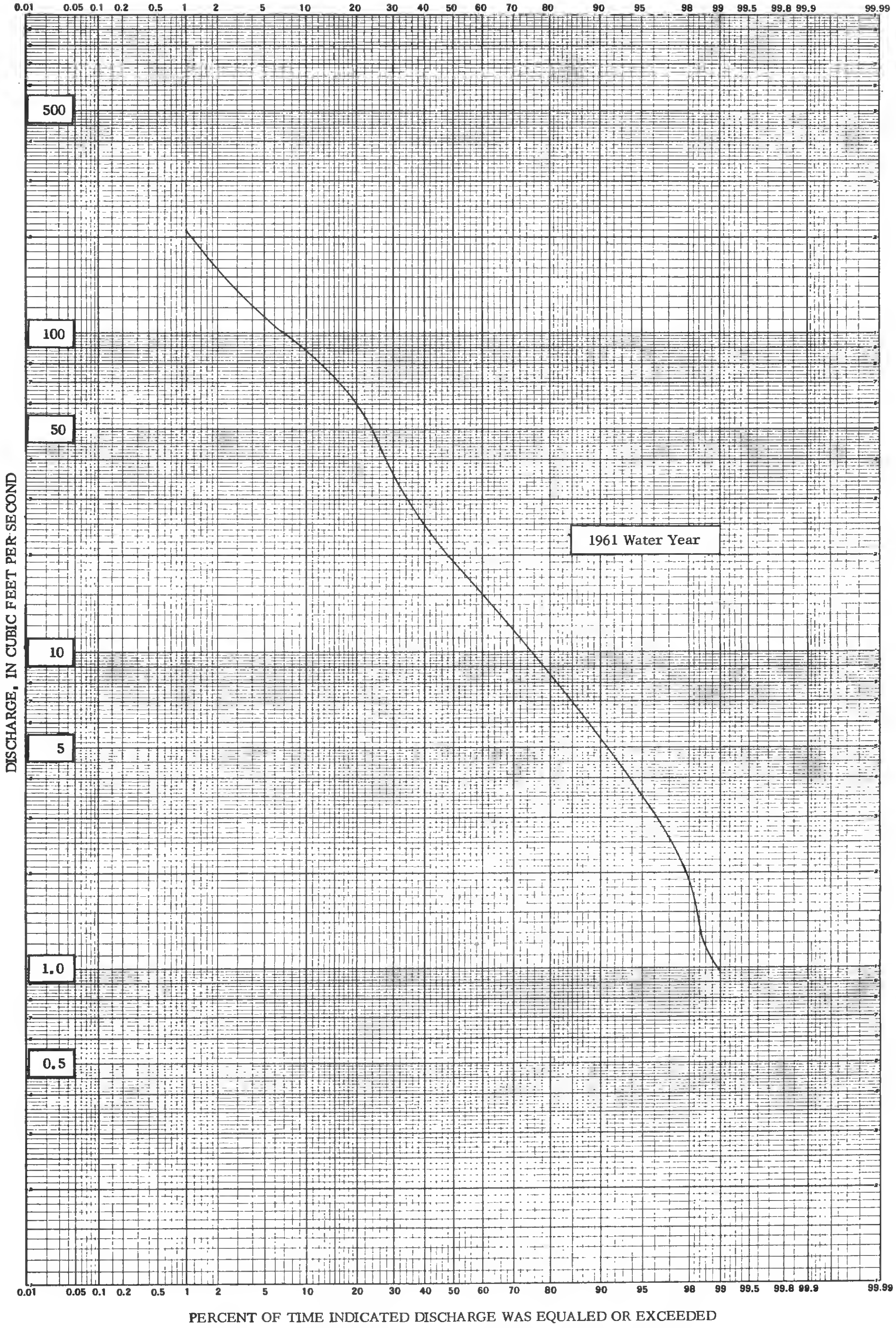

Figure 9.--Duration curve of daily flow, Cedar Pond Brook at Stony Point, N. Y.

Table 4. - Monthly and annual runoff in CSM, Cedar Pond Brook Basin

	Drainage Area	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Year
1960 Water Year														
Lake Tiorati Brook	10.5	2.00	2.89	4.14	3.07	4.30	2.21	4.41	1.78	.804	1.41	3.12	3.12	2.76
Int. Area	6.76	-	1.91	2.99	2.66	3.85	1.63	3.17	2.32	.454	.851	1.40	2.17	-
*Cedar Pond Brook	17.3	-	2.50	3.68	2.90	4.12	1.98	3.91	1.99	.665	1.18	2.44	2.75	-
1961 Water Year														
Lake Tiorati Brook	10.5	0.702	1.71	1.40	1.50	4.57	5.84	5.81	3.80	1.39	.598	1.21	.459	2.35
Int. Area	6.76	0.935	.939	.891	1.48	3.45	3.83	2.77	1.92	.626	.493	.843	.737	1.57
*Cedar Pond Brook	17.3	0.792	1.08	1.20	1.49	4.12	5.03	4.60	3.06	1.09	.555	1.06	.566	2.04

* Not adjusted for average diversion of 1.25 cfs.

Although, generally, the chemical quality of water from Cedar Pond Brook was good, concentrations of iron and manganese could impair the utility of the water. When the dissolved-solids content was about 53 ppm, the concentration of iron was 0.15 ppm and that of manganese also 0.15 ppm. At times, during the summer months, the dissolved-solids content was as high as 121 ppm, and the concentration of iron and manganese would be expected to be higher.

Detailed chemical analyses of water from Cedar Pond Brook are given in table 5.

Table 5. - Chemical analyses, Cedar Pond Brook at Stony Point

(parts per million)

Date of collection	9/1/59	12/3/59	7/13/60	8/31/61
Silica (SiO_2)		9.6		
Iron (Fe)		.15		
Manganese (Mn)		.15		
Calcium (Ca)		8.8		
Magnesium (Mg)		2.0		
Sodium (Na)		2.9		
Potassium (K)		.7		
Bicarbonate (HCO_3)	31	17	78	37
Sulfate (SO_4)		18		
Chloride (Cl)		4.5		
Fluoride (F)		.1		
Nitrate (NO_3)		.9		
Dissolved solids Residue on evaporation at 180°C		53		
Hardness as $CaCO_3$	43	30	87	47
Specific conductance (micromhos at 25°C)	97	86	201	118
pH	7.3	6.5	7.6	6.5
Color		4		
Temperature °F	72	41	67	70

MINISCEONGO CREEK BASIN

Minisceongo Creek drains a total area of 19.0 square miles, in the north-central part of the County. The main stream of this basin rises in Lake Welch (located within the Palisades Interstate Park at an elevation of 1010 feet), and flows eastward for 1 1/2 miles to a point where it receives additional flow from Horse Chock Brook. Considerable regulation can take place at Lake Welch Outlet.

Horse Chock Brook rises in Third Reservoir at elevation 1076 feet and flows through Second Reservoir and First Reservoir. These three reservoirs, with a combined capacity of 176 million gallons are used for water supply for the New York State Mental Institution at Letchworth Village. The average diversion was 1.0 cfs during the period 1959-61, according to records at Letchworth Village. A part of this diverted water returns to the Minisceongo Creek as sewage effluent but not until it has reached tide water near its mouth.

After receiving the flow from Horse Chock Creek, Minisceongo Creek flows east for one mile and then south for a mile through the grounds of Letchworth Village to a point where it is joined by South Branch of Minisceongo Creek.

South Branch rises near Summit Park and flows about one mile north into Mount Ivy Swamp. From there it flows sluggishly northeast for 1 1/2 miles before joining the main branch. From this point of junction Minisceongo Creek flows a half mile south and then northeast one mile to Thiells.

Minisceongo Creek at Thiells

At Thiells, the flow in Minisceongo Creek ranged from 1.7 to 747 cfs in 1960 and from 1.9 to 398 cfs in 1961. During the period of record a peak flow in excess of 300 cfs occurred five times (table 6).

Although the total rainfall in 1960 was nearly 14 inches greater than in 1961 the total runoff for each year was almost the same, 27.94 inches in 1960 and 27.83 inches in 1961. This anomaly resulted from a difference in rainfall distribution during the years rather than any change in geologic or vegetal conditions throughout the basin.

Figure 10 shows the flow duration curves for Minisceongo Creek for the water years 1960 and 1961. During both years a flow of 7 cfs or more occurred about 86 percent of the time and one in excess of 29 cfs, 34 percent of the time. The bulges in the curves are attributable to rainfall distribution rather than any peculiar basin characteristic. Low flows can be modified by any change that may take place in diversion for use at Letchworth Village or as a result of regulation at Lake Welch outlet. The record of spillage from First Reservoir indicates that on an average, spillage takes place 265 days each year and the rest of the time the area above the reservoir is non-contributing to the flow of Minisceongo Creek. However, during the two water years of study, spillage from First Reservoir occurred on all but a total of less than fifty days.

Table 6. - Summary of Streamflow, Minisceongo Creek at Thiells, 1959-61

Location.--Lat 41°12'34", long 74°01'16", on left bank at old mill dam, 250 ft upstream from Rosman Road bridge, at Thiells, 3/4 mile upstream from Garnerville Reservoir, and 1 1/4 miles downstream from South Branch Minisceongo Creek.

Drainage area.--15.0 sq mi.

Records available.--October 1959 to December 1961.

Gage.--Water-stage recorder. Altitude of gage is 285 ft (from topographic map).

Extremes.--1959-60: Maximum discharge during water year, 747 cfs Aug. 19 (gage height, 3.45 ft); minimum, 1.7 cfs July 26.

1960-61: Maximum discharge during water year, 398 cfs Feb. 25 (gage height, 2.82 ft); minimum, 1.9 cfs Sept. 19.

Remarks.--Records good. Flow regulated by lakes and reservoirs above station.

Monthly and yearly mean discharge, in cubic feet per second

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The Year
1960	24.1	30.7	50.7	37.3	45.7	23.3	44.7	21.3	9.60	15.3	28.0	39.6	30.8
1961	48.1	22.5	16.0	16.8	45.8	88.0	57.2	33.1	13.6	13.8	10.3	4.40	30.8

Monthly and yearly runoff, in inches (unadjusted)

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The Year
1960	1.85	2.29	3.90	2.87	3.29	1.79	3.33	1.64	0.71	1.17	2.15	2.95	27.94
1961	3.70	1.68	1.23	1.29	3.18	6.76	4.25	2.55	1.01	1.06	0.79	0.33	27.83

Peak discharge (base, 225 cfs)

Date	Time	Gage Height (ft)	Discharge (cfs)	Date	Time	Gage Height (ft)	Discharge (cfs)
1-3-60	10:00 am	2.58	301	2-25-61	1:30 pm	2.82	398
7-30-60	12:30 pm	2.79	385	4-16-61	4:00 pm	2.55	290
8-19-60	11:30 am	3.48	747	8-26-61	4:00 pm	2.37	228
9-12-60	4:30 pm	2.79	385				

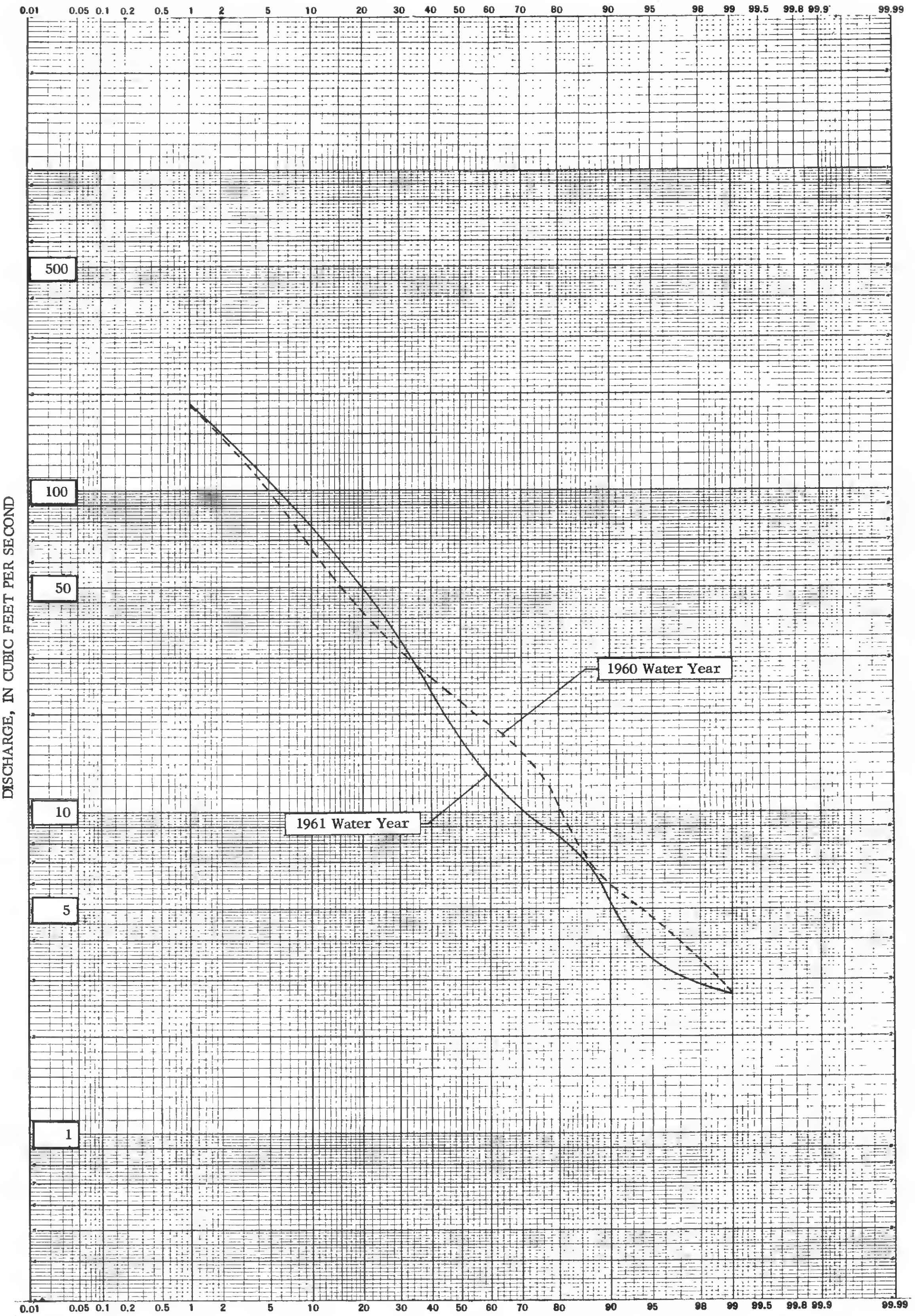

Figure 10.--Duration curves of daily flow, Minisceongo Creek at Thiells, N. Y.

Below Thiells, Minisceongo Creek receives the inflow from two small tributaries (one from the north through a series of ponds and swamp area, and one from the south), before it enters Garnerville Reservoir at Garnerville. This reservoir is used for regulatory purposes and some water is also diverted for industrial use. Excess water spills over into a somewhat smaller pond which in turn spills into a third pond before the Creek passes through a lengthy tunnel under the Garnerville Holding Corporation manufacturing plant. From the east side of the plant the Creek passes through a deep gorge and out to tidewater of the Hudson River.

Generally, the chemical quality of water from Minisceongo Creek was satisfactory for most purposes. Specific conductance measurements indicate the dissolved-solids content was about 110 ppm in two samples. Another water sample contained 69 ppm of dissolved solids (table 7). The hardness of the water in three samples varied from 40 to 83 ppm. Such water would be classified as soft to moderately hard.

Although, generally, the chemical quality of water was satisfactory, iron and manganese concentrations could present a problem. In one water sample, the iron concentration was 0.37 ppm and that of manganese 0.18 ppm. The iron concentration alone would precipitate and would produce brown stains. The presence of manganese would aggravate the condition; it would produce black stains.

Only one water sample was collected for the determination of suspended sediment. It contained 36 ppm of sediment in suspension. The discharge at the time of sample collection was 152 cfs. Assuming that the rate of discharge and the concentration did not change, the estimated sediment load passing Thiells would have been 15 tons per day on the day measured. However, such sediment loads would probably be infrequent since mean daily flows equal to or in excess of 152 cfs can be expected only 2 percent of the time (fig. 10).

South Branch Minisceongo Creek at Letchworth Village

A partial-record station was established early in the 1960 water year on South Branch Minisceongo Creek at a site 1,000 ft downstream from the Palisades Interstate Parkway. Eleven discharge measurements have been made at this site, seven of these under base-flow conditions. The results of the measurements appear in Table 8. Because of the relatively high-flow conditions existing during the past two years, insufficient low-flow data are available to develop duration of flow curves for this site.

Water samples collected from South Branch Minisceongo Creek at Letchworth Village contained more dissolved solids than those from Minisceongo Creek. One sample had a dissolved-solids content of 109 ppm. Concentrations of dissolved solids (computed from specific conductance measurements) in two other samples were about 150 ppm. The hardness of the water in three samples ranged from 71 to 112 ppm (table 9). The water in all samples would be classified as moderately hard whereas in one sample from Minisceongo Creek the hardness was 40 ppm, a soft water.

Table 7. - Chemical analyses, Minisceongo Creek at Thiells, N. Y.

(parts per million)

Date of collection	9/1/59	12/3/59	8/31/61
Silica (SiO_2)		9.4	
Iron (Fe)		.37	
Manganese (Mn)		.18	
Calcium (Ca)		11	
Magnesium (Mg)		3.0	
Sodium (Na)		3.8	
Potassium (K)		.9	
Bicarbonate (HCO_3)	74	20	63
Sulfate (SO_4)		22	
Chloride (Cl)		5.0	
Fluoride (F)		.1	
Nitrate (NO_3)		2.6	
Dissolved solids			
Residue on evaporation at 180°C		69	
Hardness as $CaCO_3$	83	40	69
Specific conductance (micromhos at 25°C)	190	109	171
pH	7.6	6.4	7.7
Color		6	
Temperature °F	72	42	73

One other significant difference in the chemical quality of the two streams was the concentrations of iron and manganese. Water from South Branch Minisceongo Creek contained less iron - 0.14 ppm. The manganese concentration was also less than that from Minisceongo Creek - 0.08 ppm. Assuming that the concentrations of iron and manganese did not increase during low-flow conditions, iron and manganese should not be a problem.

Table 8. - Summary of Discharge Measurements, South Branch Minisceongo Creek at Letchworth Village

Date	Discharge (cfs)	Date	Discharge (cfs)
July 20, 1959	1.21	June 1, 1960	7.01
Oct. 8, 1959	1.18	Sept. 27, 1960	5.27
Oct. 29, 1959	3.83	Sept. 21, 1961	6.79
Nov. 8, 1959	15.1	Oct. 6, 1961	2.71
Feb. 12, 1960	37.5	Mar. 20, 1962	18.5
Apr. 8, 1960	26.2		

Table 9. - Chemical analyses, South Branch Minisceongo Creek at Letchworth Village

(parts per million)

Date of collection	9/1/59	12/3/59	8/31/61
Silica (SiO_2)		9.8	
Iron (Fe)		.14	
Manganese (Mn)		.08	
Calcium (Ca)		20	
Magnesium (Mg)		5.1	
Sodium (Na)		4.0	
Potassium (K)		8	
Bicarbonate (HCO_3)	111	55	112
Sulfate (SO_4)		25	
Chloride (Cl)		6.6	
Fluoride (F)		.1	
Nitrate (NO_3)		.9	
Dissolved solids Residue on evaporation at 180°C		109	
Hardness as $CaCO_3$	112	71	79
Specific conductance (micromhos at 25°C)	231	173	231
pH	7.4	7.0	7.3
Color		15	
Temperature °F		38	

SPARKILL CREEK BASIN

Sparkill Creek rises in a portion of the Palisades Interstate Park in the Town of Orangetown at an elevation of 450 feet and discharges directly into the Hudson River. The entire stream has a length of 8 1/4 miles from its source to its mouth (fig. 6). The headwaters of the Creek flow west for three-quarters of a mile, then south one and one-quarter miles to a small pond (elevation 63 feet) just east of Orangeburg. A short distance below the pond, Sparkill Creek is joined by three small tributaries and then flows through a swamp area.

Sparkill Creek at Tappan

About a mile downstream from the swamp, at Washington Street bridge in the Village of Tappan, the minimum flow in 1960 was 1 cfs and in 1961, 0.9 cfs. The maximum flows for these two years were 440 and 181 cfs, respectively. A peak discharge of 150 cfs or more was reached on five occasions (table 10).

Figure 11 is the duration curve for the flow in Sparkill Creek at the Tappan gage. Note the slope of the upper and lower extremes of this curve indicating rapid high-water runoff and sustained low flows.

The bulge between the 40 and 75 percent duration points on the curve was due partly to release to the stream of sewage during a period of about 4 weeks in 1960 while repairs were being made to a main trunk sewer normally carrying waste directly to the Hudson River.

Figure 12 is a plot of mean daily water temperature of Sparkill Creek as determined at the Tappan gage, and mean daily air temperature as recorded at Dobbs Ferry for the water year Oct. 1, 1960 to Sept. 30, 1961. Detailed temperature data are given in Table 43.

As one would expect, the minimum water temperatures occurred during December, January and February, when the average air temperatures were lowest. A definite warming trend started in mid-March and continued through mid-September after which both air and water temperatures started a downward trend. Attention is called to the fact that, in general, through the period June to late September, air temperatures averaged higher than water temperatures and varied considerably more on a day-to-day basis. Usually, air temperatures during a day have a greater range than water temperatures (fig. 13). Part of the spread is due undoubtedly to the rather uniform temperature of the ground-water contribution to streamflow especially in times of low flow when ground water may constitute a large percentage of total streamflow.

Temperature data of Rockland County streams are important in the future development of the County since water of suitable temperature is desirable for domestic use as well as for industrial cooling and processing. It is quite possible that the temperature of water from Sparkill Creek may be somewhat higher than that of some other County streams due to the discharge of warm industrial wastes a short distance above the Tappan gage. This discharge averaged about 0.5 cfs at a temperature often 10 or more degrees above air temperature during the summer months.

Table 10. - Summary of Streamflow, Sparkill Creek at Tappan, 1959-61

Location.--Lat 41°01'26", long 73°56'52", on left bank, 100 ft downstream from Kings Highway bridge, at Tappan, 1/2 mile upstream from New York-New Jersey State line, and 1 mile upstream from Sparkill Brook.

Drainage area.--4.94 sq mi.

Records available.--October 1959 to December 1961.

Gage.--Water-stage recorder. Altitude of gage is 38 ft (from topographic map). Nov. 5 to Dec. 10, 1959, staff gage at same site and datum.

Extremes.--1959-60: Maximum discharge during water year, 440 cfs Aug. 19 (gage height, 4.65 ft); minimum recorded, 1.0 cfs July 23.
1960-61: Maximum discharge during water year, 181 cfs July 24 (gage height, 3.02 ft); minimum, 0.9 cfs July 11.

Remarks.--Records good. Diurnal fluctuations from manufacturing plant sewer outfall above station. Water temperature since December 1959.

Monthly and yearly mean discharge, in cubic feet per second

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The Year
1960	5.77	8.43	11.2	9.66	15.9	7.69	12.4	7.95	3.88	5.51	9.90	11.7	9.13
1961	3.82	5.92	5.35	6.49	17.7	15.2	17.0	7.11	2.80	7.06	5.42	2.78	7.99

Monthly and yearly runoff, in inches

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The Year
1960	1.35	1.90	2.62	2.25	3.47	1.79	2.81	1.86	0.88	1.29	2.31	2.64	25.17
1961	0.89	1.34	1.25	1.51	3.74	3.56	3.83	1.66	0.63	1.65	1.26	0.63	21.95

Peak discharge (base, 100 cfs)

Date	Time	Gage Height (ft)	Discharge (cfs)	Date	Time	Gage Height (ft)	Discharge (cfs)
1-3-60	12:01 pm	2.44	120	3-14-61	9:30 am	2.36	112
2-19-60	6:00 am	2.72	147	4-16-61	5:15 pm	2.75	150
7-3-60	8:00 pm	2.35	112	7-15-61	8:00 pm	2.38	114
7-30-60	11:00 am	3.16	199	7-20-61	10:45 am	2.64	139
8-19-60	1:30 pm	4.65	440	7-24-61	2:15 pm	3.02	181
9-12-60	5:30 pm	3.90	304	8-26-61	11:15 pm	2.74	149
2-26-61	1:45 am	2.61	136				

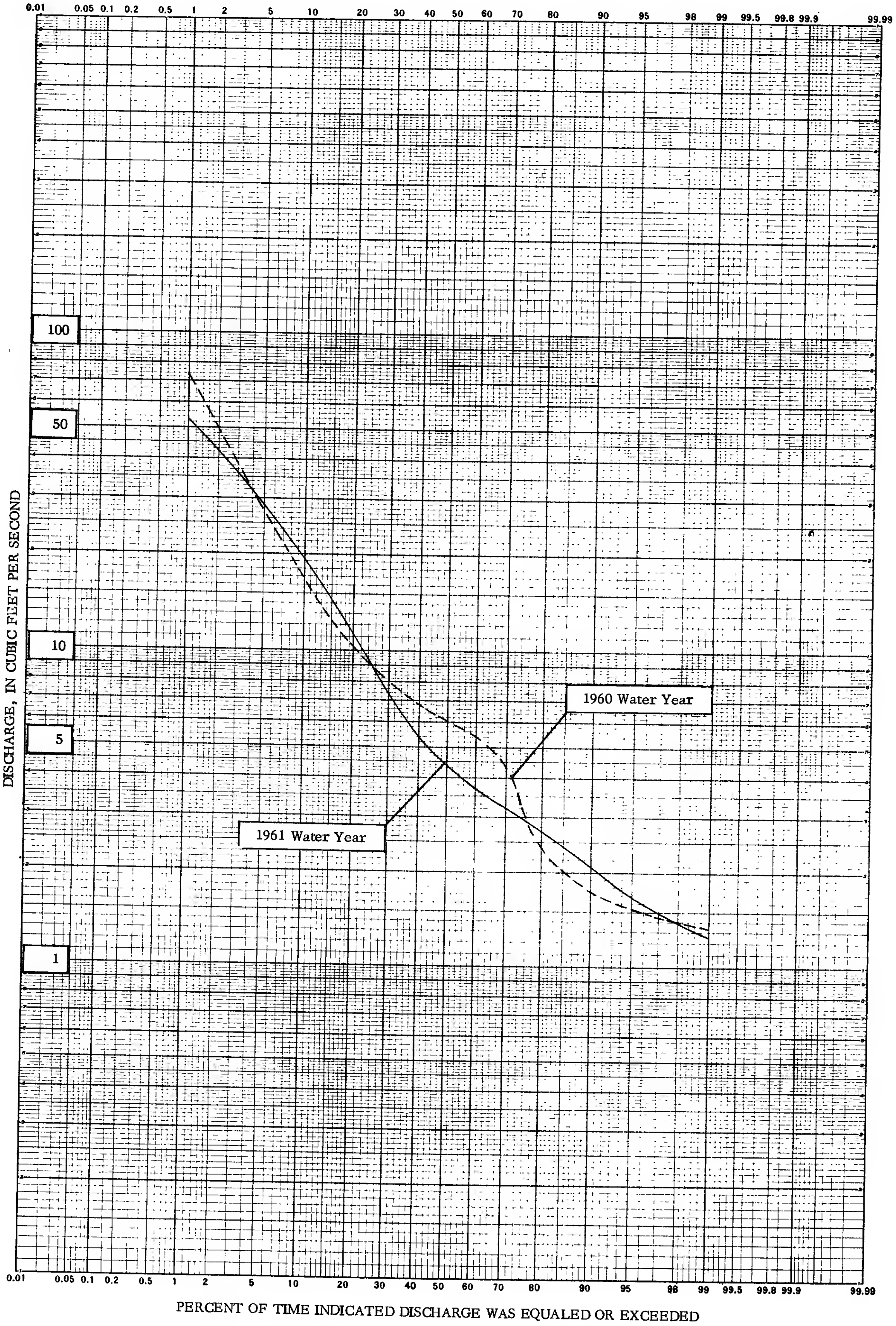

Figure 11.--Duration curves of daily flow, Sparkill Creek at Tappan, N.Y.

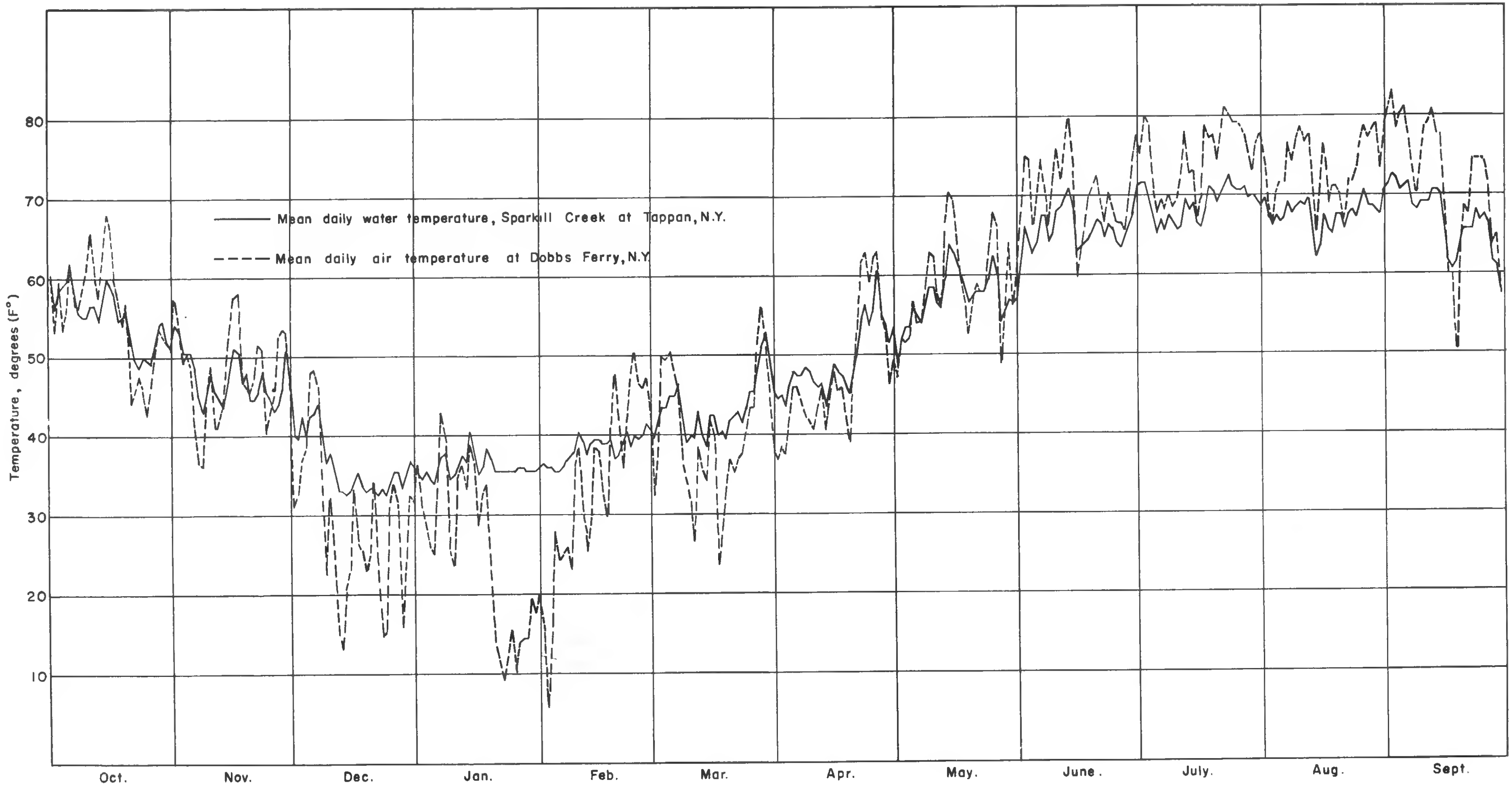

Figure 12.– Mean daily water temperature of Sparkill Creek at Tappan, and air temperature at Dobbs Ferry, 1961 water year.

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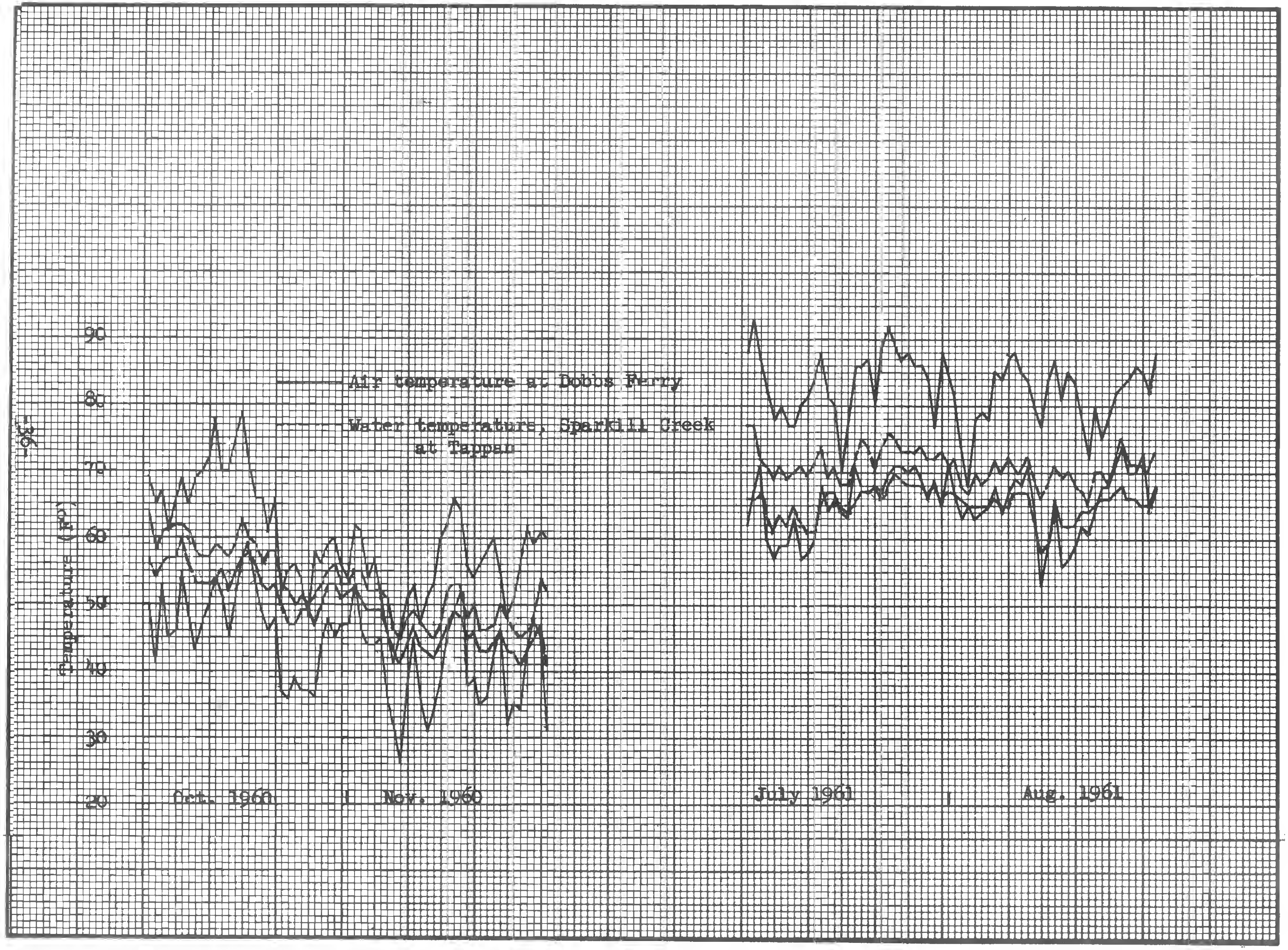
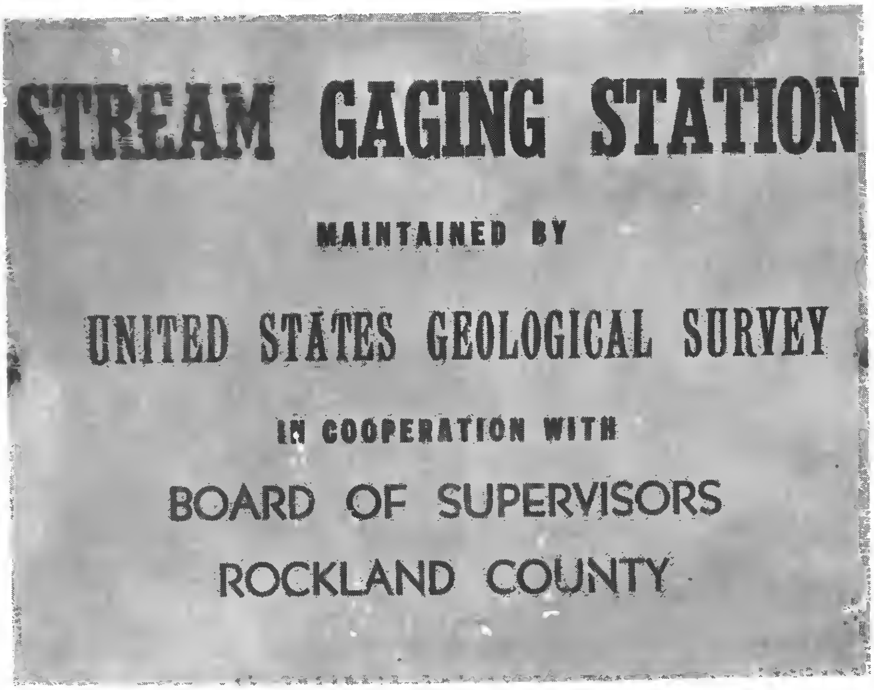


Figure 13.--Maximum and minimum water temperatures of Sparkill Creek at Tappan, and air temperatures at Dobbs Ferry, October - November 1960, and July - August 1961

Typical Rockland County Stream-gaging Station



Cooperation sign used to identify gaging structures.

Sparkill Creek at Sparkill

Below the Tappan gage Sparkill Creek flows south through the village of Tappan and to the New York-New Jersey state line nearly a half mile away, southeast for half a mile along the state line, and then northeast to tidewater. At a point between Tappan and the state line an average of 0.44 mgd of treated sewage is discharged from Rockland State Hospital into Sparkill Creek.

Downstream from its first crossing of the state line, the Creek flows for about 1/2 mile through a swamp area and is joined by its major tributary, Sparkill Brook which flows northward out of a very swampy area in Northern New Jersey.

During the water year 1960 the flow in Sparkill Creek at Sparkill varied from a maximum of 393 cfs to a minimum of 1.4 cfs and in 1961 from 280 to 1.0 cfs (table 11). The average for the two-year period was 20.6 cfs. A peak discharge in excess of 200 cfs occurred on six occasions during the two-year period. In 1960, nearly 27 inches of the 57 inches of precipitation appeared as streamflow while in 1961 nearly 24 inches of runoff was realized from about 44 inches of precipitation. These values of runoff amount to 47 and 55 percent of the precipitation.

From the duration curve for this site, the character of flow for the two years 1960, 1961 can be seen (fig. 14). During both years of record a flow equal to or in excess of 50 cfs occurred about 8 percent of the time while flows equal to or in excess of 5 cfs occurred 90 percent of the time.

According to the New York State Health Department, Water Pollution Control Board (1951), the headwaters of Sparkill Creek are relatively unpolluted. However, at Tappan and Sparkill, pollution was present and was reflected in the chemical quality of water samples from Sparkill Creek.

At both locations, the quality was poor. On December 3, 1959, the dissolved-solids content was 191 ppm at Tappan and 195 ppm at Sparkill (table 12). The water was hard.

Iron and manganese concentrations were sufficient to cause brown and black stain if not removed before the water was used. The alkalinity was sufficient to maintain an alkaline condition; the pH of the water was above 7.0 in four samples and as high as 8.0 in one sample.

Table 11. - Summary of Streamflow, Sparkill Creek at Sparkill, 1959-61

Location.--41°01'44", long 73°55'34", on right downstream wingwall of New Street bridge, at Sparkill, 1 1/4 miles upstream from mouth, and about 1 1/4 miles downstream from Sparkill Brook.

Drainage area.--11.1 sq mi.

Records available.--September 1959 to December 1961.

Gage.--Water-stage recorder. Altitude of gage is 10 ft (from topographic map).

Extremes.--1959: Minimum discharge during period Sept. 17-30, 1.4 cfs Sept. 18,21,22.

1959-60: Maximum discharge during water year, 393 cfs Sept. 13 (gage height, 3.70 ft); minimum, 1.4 cfs July 25.

1960-61: Maximum discharge during water year, 280 cfs Feb. 26 (gage height, 3.25 ft); minimum, 1.0 cfs July 12,13.

Remarks.--Records good. Sewage effluent discharged into Sparkill Brook, an upstream tributary.

Monthly and yearly mean discharge, in cubic feet per second

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The Year
1960	14.4	20.7	29.4	23.5	39.3	19.7	27.6	16.6	9.51	12.9	20.3	27.7	21.7
1961	9.97	14.3	13.4	16.6	42.9	37.8	41.6	15.7	7.90	15.4	15.2	6.48	19.6

Monthly and yearly runoff, in inches

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The Year
1960	1.49	2.08	3.06	2.45	3.82	2.05	2.77	1.73	0.96	1.34	2.11	2.78	26.64
1961	1.04	1.44	1.39	1.73	4.02	3.92	4.18	1.63	0.79	1.60	1.58	0.65	23.95

Peak discharge (base, 150 cfs)

Date	Time	Gage Height (ft)	Discharge (cfs)	Date	Time	Gage Height (ft)	Discharge (cfs)
1-3-60	7-8 pm	2.66	161	9-13-60	1:00 am	3.70	393
2-11-60	5:00 pm	2.65	160	2-26-61	6:30 am	3.25	280
2-19-60	1-2 pm	3.08	242	3-14-61	5:00 pm	2.87	199
2-26-60	11:00 am	2.60	151	4-13-61	4:30 pm	2.75	177
4-5-60	5:00 pm	2.73	173	4-16-61	12:00 pm	3.03	231
7-30-60	10:00 pm	2.84	194	4-18-61	10:00 pm	2.66	161
8-19-60	10-11 pm	3.65	380	8-27-61	8:30 am	2.98	221

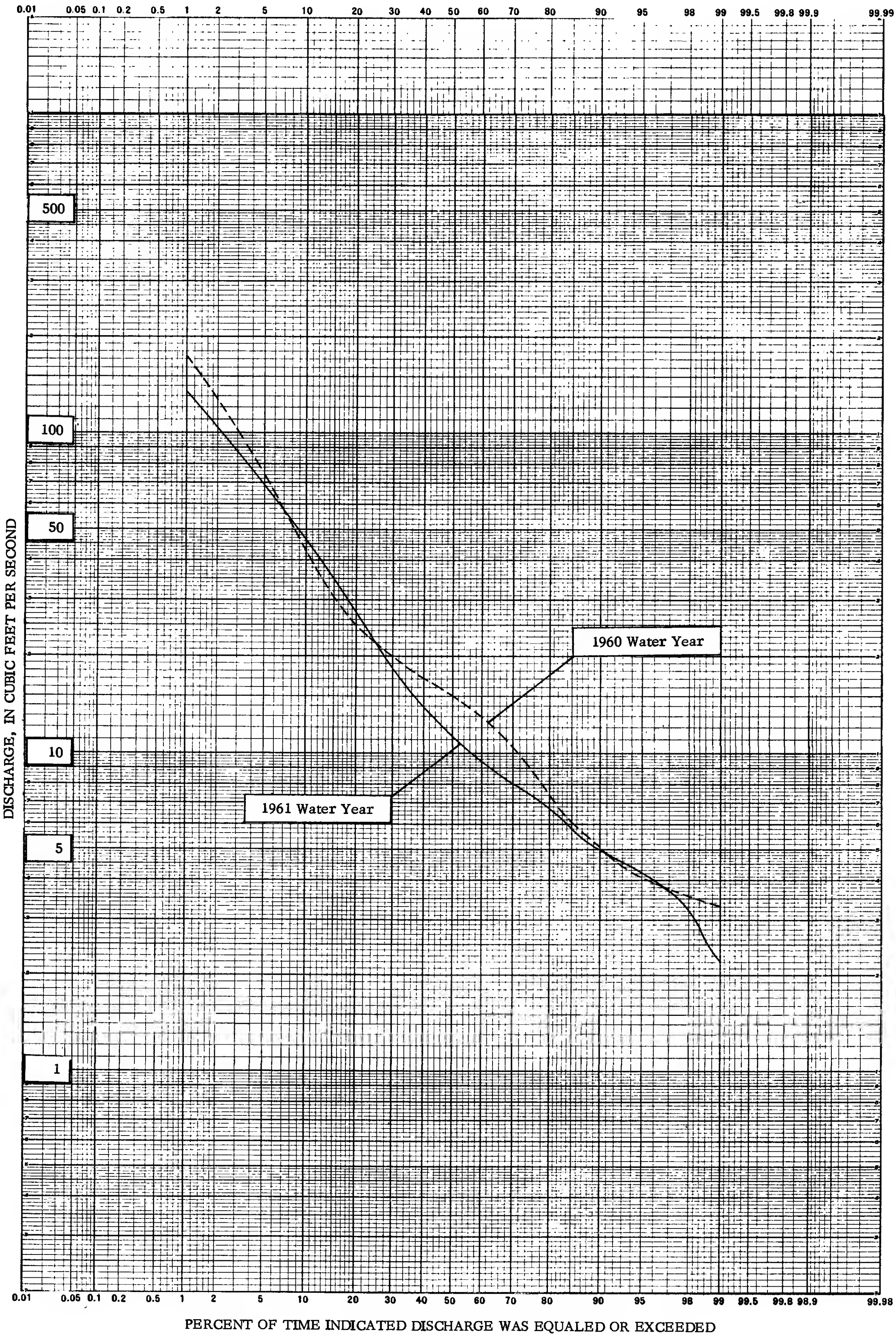


Figure 14. --Duration curves of daily flow, Sparkill Creek at Sparkill, N. Y.

Table 12. - Chemical analyses, Sparkill Creek

(parts per million)

Location	TAPPAN		SPARKILL	
Date of collection	12/3/59	8/31/61	12/3/59	8/31/61
Silica (SiO_2)	18		18	
Iron (Fe)	.14		.24	
Manganese (Mn)	.13		.21	
Calcium (Ca)	34		32	
Magnesium (Mg)	9.6		9.3	
Sodium (Na)	9.0		13	
Potassium (K)	1.0		2.3	
Bicarbonate (HCO_3)	94	176	88	136
Sulfate (SO_4)	52		51	
Chloride (Cl)	10		14	
Fluoride (F)	.1		.3	
Nitrate (NO_3)	4.5		9.0	
Dissolved solids				
Residue on evaporation at 180°C	191		195	
Hardness as $CaCO_3$	125	180	118	164
Specific conductance (micromhos at 25°C)	308	408	321	388
pH	8.0	7.2	7.3	6.8
Color	7		6	
Temperature °F	44	75	44	76

Water samples collected from Sparkill Creek during low flow contained 27 and 30 ppm of suspended sediment. The estimated sediment load was about 0.1 ton per day. When streamflow rose to 54 and 60 cfs, the concentration of suspended sediment increased to 187 and 113 ppm, respectively. Under such conditions of discharge and concentration, the instantaneous sediment discharge was at the rate of 27 and 18 tons per day.

The relatively large amount of swamp area in the Sparkill Creek Basin provides a natural flood-control feature which may be lost because of urbanization. Filling in of the swamp area as part of the urbanization process, and the substitution of house roofs and blacktop driveways and streets, will undoubtedly change runoff characteristics and affect the shape of the upper end of the duration curve. It is too early yet to determine what effect if any would be noticeable at the lower end. At the time of writing of this report (1962) the County Planning Board has been advised that a large industrial plant was to be erected on Sparkill Brook in Northern New Jersey. There was also a possibility Rockland State Hospital sewage effluent might be carried directly to the Hudson River. Either of these proposals could seriously affect the volume of water passing the Sparkill gage during low flows, which in turn could influence operations at Continental Can Co. in Piermont downstream where an average of 4.6 cfs of water is used for processing.

HACKENSACK RIVER BASIN

Hackensack River is the largest of all the streams whose upper reaches lie entirely within Rockland County. This river has its source adjacent to the Palisades Interstate Parkway just east of Pomona at an elevation of 520 feet. From here the stream flows north-northeast about 1 1/2 miles to the foothills of South Mountain and follows easterly along the base of this mountain 1 1/2 miles to Lake Lucille, a small lake used primarily for recreational purposes. Although a small dam and outlet structure have been constructed, there is no evidence of any significant regulation. From Lake Lucille, the river travels about one mile southeast where it is joined at elevation 95 feet by a sizeable tributary which rises in the vicinity of New City Park. From this junction point Hackensack River flows three-fourths of a mile southeast into the northwest section of DeForest Lake.

Hackensack River at Brookside Park

Flow of the Hackensack River at Brookside Park during the 1960 water year varied from 4.4 to 1,010 cfs, and in 1961 from 4.8 to 537 cfs (table 13). The average flow for the two years was 27.2 and 27.1 cfs. This rate of flow corresponds to a total runoff of about 28 inches during both years corresponding to about 50 and 68 percent, respectively, of the precipitation for each year.

Figure 15 presents duration-of-flow curves for this gaging station; the solid line is for the 1961 water year, the dashed line for 1960, and the broken line is the curve developed by correlation with records for long-term gaging stations in the general area.

These curves show that the flow during the periods 1960, 1961 was higher than that to be expected over a long period of time, particularly below the 50 percent duration level. From the curve based on the reference period (1935-61), a flow equal to or exceeding 5 cfs can be expected 90 percent of the time and a flow of 50 cfs or greater nearly 10 percent of the time. From this figure the danger of using the record for any single year to predict the future pattern of flow on a stream should be obvious. However, in this particular case the average annual flow which generally occurs near the 30 percent point on the duration curve, would have been defined by any one of the three curves.

Monthly and annual totals of rainfall at this site compare favorably with those collected at the Cedar Flats gage and with those collected at other sites throughout Rockland County. (See appendix table 42a).

The amount and distribution of rainfall during an individual storm may vary considerably from one part of the County to another. During the storm of Aug. 26, 1961, although 4.68 inches of rain were recorded at Cedar Flats, only 1.18 inches fell at Brookside Park, and 1.23 inches at Suffern. On the other hand, 4.32 inches were reported at the Tompkins Cove.

Table 13. - Summary of Streamflow, Hackensack River at Brookside Park, 1959-61

Location.--Lat 41°10'18", long 73°58'24", on right bank at Brookside Park, 900 ft upstream from State Highway 304, 1,300 ft upstream from DeForest Lake, 3/4 mile downstream from unnamed tributary, and 1 1/4 miles downstream from Lake Lucille.

Drainage area.--13.2 sq mi.

Records available.--October 1959 to December 1961.

Gage.--Water-stage recorder. Altitude of gage is 90 ft (from topographic map).

Extremes.--1959-60: Maximum discharge during water year, 1,010 cfs Aug. 19 (gage height, 6.67 ft); minimum recorded, 4.4 cfs July 27.

1960-61: Maximum discharge during water year, 537 cfs Apr. 16 (gage height, 5.32 ft); minimum, 4.8 cfs Aug. 18, Sept. 13, 18, 19.

Remarks.--Records good. Very infrequent regulation by Lake Lucille. Precipitation record at site since May 1960.

Monthly and yearly mean discharge, in cubic feet per second

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The Year
1960	17.4	20.1	38.4	32.9	47.7	24.5	37.9	18.6	11.2	19.6	26.0	33.9	27.2
1961	21.2	20.2	16.2	18.5	55.5	64.0	56.3	31.2	13.5	14.6	9.93	6.71	27.1

Monthly and yearly runoff, in inches

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The Year
1960	1.52	1.69	3.35	2.87	3.90	2.14	3.20	1.62	0.94	1.71	2.27	2.86	28.07
1961	1.85	1.71	1.42	1.62	4.38	5.59	4.76	2.72	1.14	1.28	0.87	0.57	27.91

Peak discharge (base, 250 cfs)

Date	Time	Gage Height (ft)	Discharge (cfs)	Date	Time	Gage Height (ft)	Discharge (cfs)
10-24-59	6:00 pm	4.29	292	8-19-60	1:30 pm	6.67	1,010
12-7-59	10:00 am	4.22	279	9-12-60	7:00 pm	5.52	596
12-29-59	7:00 am	4.38	310	10-17-60	12:15 am	4.06	250
1-3-60	4:00 pm	4.19	273	2-26-61	5:00 am	5.13	484
2-11-60	2:00 pm	4.30	294	4-16-61	9:00 pm	5.32	537
7-30-60	3:30 pm	5.62	626				

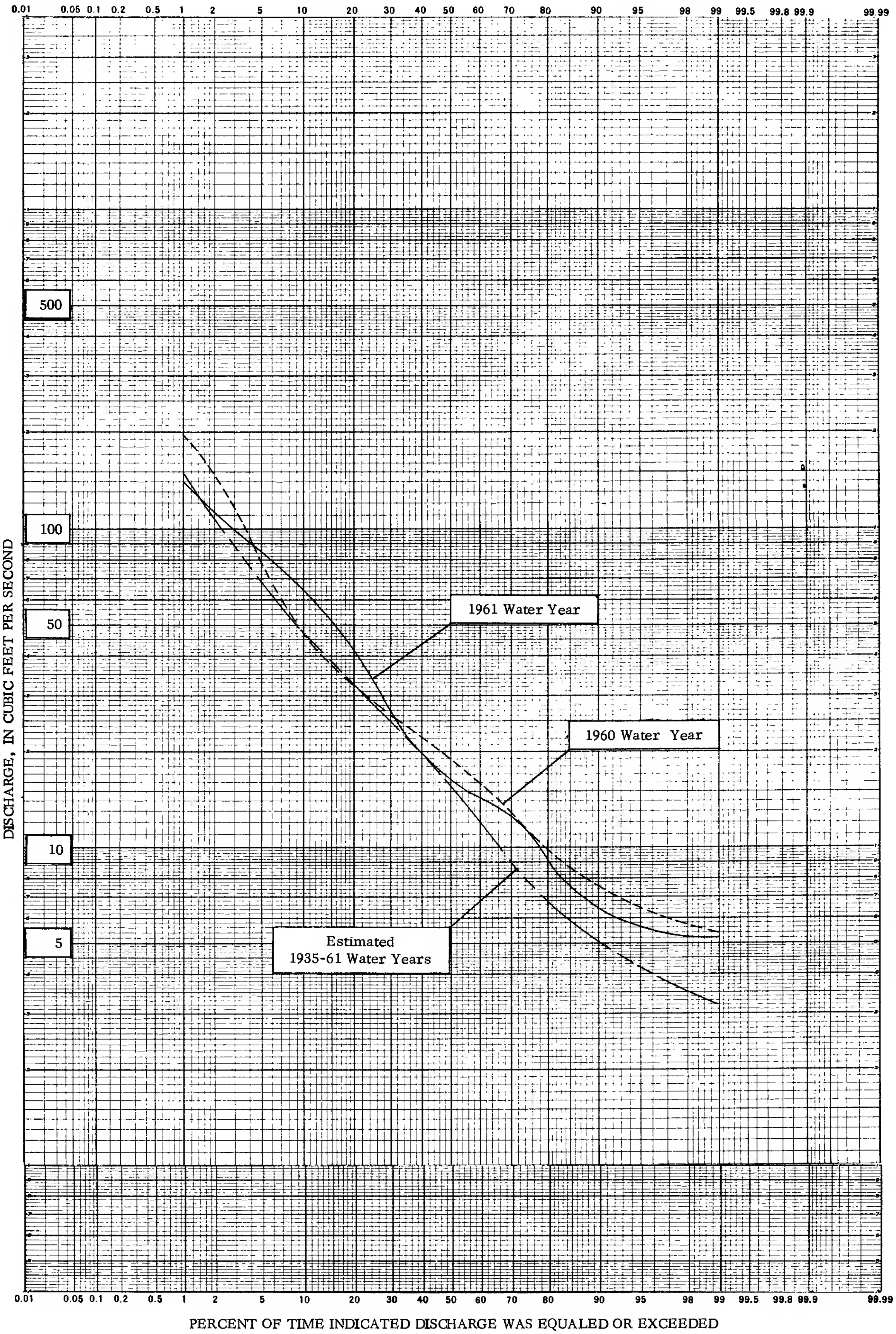


Figure 15.--Duration curves of daily flow, Hackensack River at Brookside Park, N. Y.

The area below the Brookside Park gaging station, downstream to Ridge Road constitutes the northwest section of DeForest Lake. During high flows this section maintains a surface elevation somewhat higher than the main body of the lake. This condition is due apparently to the inability of the culvert system under Ridge Road to pass water from the section into the main lake until there is sufficient head to force the water through the culverts. It is estimated that, at times, this difference in water-surface elevation may exceed a foot.

Besides being fed from the main Hackensack River, DeForest Lake receives the flow of Toms Brook from the north and East Branch Hackensack River from the east.

Usually, at Brookside Park, water samples from the Hackensack River contained less dissolved solids than those collected at two downstream locations and from two major tributaries (table 14 and fig. 16). The approximate range of concentrations of dissolved solids was from 82 to 119 ppm, calculated from specific conductance measurements. Concentrations in the upper part of the range were present in water samples collected during low-flow periods when the flow averaged about 6 cfs. In the lower part of the range, as stream discharge increased, dilution reduced the concentrations of dissolved solids.

However, a substantial increase in stream discharge was necessary to effect a sizeable reduction in dissolved-solids concentration. A review of table 14 shows that when the discharge of the Hackensack River was 6.2, 51, and 151 cfs, the specific conductance was 198, 170, and 136 micromhs, respectively. Although there was over a twentyfold increase in the water discharge between the lowest and highest sampled discharge there was only about a 30 percent decrease in dissolved-solids content, as indicated by the specific conductance. It is not known if the pattern of reduction in dissolved solids would continue with further increase in discharge. The usual pattern in a discharge-dissolved solids relationship is an initial sharp drop in concentration of dissolved solids followed by only a small reduction in concentration as stream discharge increases.

Such a change in dissolved solids would be considered moderate. Whether it would be significant would depend on the use of the water. For domestic use, the change in concentration of dissolved solids would not affect the potability of water. For some sensitive industrial processes, such a change might be important. The chemical composition of water from the Hackensack River consists principally of calcium and bicarbonate. The concentrations of sulfate are about half of those for bicarbonate. Concentrations of other constituents (except iron, as will be discussed later) contributed very little to the dissolved-solids content.

Table 14. - Chemical analyses of streams

Hackensack River basin

(parts per million)

Date of collection	Discharge (cfs)	Water temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$		Specific conductance (micromhos at 25°C)	pH	Color
																Ca, Mg	Non-carbonate			
										Hackensack River at Brookside Park										
Sept. 1, 1959		73								50						70		156	7.2	
Dec. 3	16	40	9.9	1.3	0.04	20	4.0	4.5	1.1	48	25	8.3	0.1	3.4	102	67	27	173	7.0	4
Feb. 11, 1960	151	46								34						52		136	6.5	
July 13	6.2	68								66						78		198	7.1	
Oct. 20	51	56								59						72		170	6.8	
Aug. 31, 1961	6.6	72								69						--		197	7.1	
										East Branch Hackensack River near Congers										
Sept. 1, 1959	9 1/	73								72						84		201	7.2	
Dec. 3	14 1/	40	7.7	.10	.05	23	5.4	4.9	1.8	56	32	10	.2	2.7	124	80	34	207	6.5	8
Feb. 11, 1960	55 1/	46								44						64		171	6.5	
July 13	.2 1/	70								117						109		252	7.0	
Oct. 20	20 1/	56								68						81		192	6.8	
Aug. 31, 1961		79								106						94		229		
										Hackensack River at West Nyack										
Sept. 1, 1959	27	72								74						82		195	7.2	
Dec. 3	40	43	4.1	.14	.24	22	4.4	3.9	1.7	60	21	5.5	.2	3.4	106	73	24	185	6.7	5
Feb. 11, 1960	256	42								48						69		176	6.5	
July 13	12	71								70						82		196	7.0	
Aug. 31, 1961	11	77								70						82		196	7.0	
										Nauraushaun Brook at Nauraushaun										
Aug. 31, 1959		73								89						96		218	7.4	
Dec. 3		41	12	.57	.19	26	5.8	7.1	1.7	66	34	12	.1	2.2	146	89	35	233	7.0	
Feb. 11, 1960	37	46								24						50		140	6.2	
July 12	3.0	73								75						91		211	7.2	
Aug. 31, 1961	2.8	78								89						96		234	7.2	
										Hackensack River at Nauraushaun										
Aug. 31, 1959		74								67						74		178	7.2	
Dec. 3	60	39	6.5	.11	.03	23	4.8	7.0	1.9	66	25	11	.1	3.4	120	77	23	208	7.1	6
Feb. 11, 1960	81	44								36						56		153	6.6	
July 12	20	76								84						91		219	7.1	
Aug. 31, 1961	19	76								89						97		246	7.2	

1/ Instantaneous discharge.

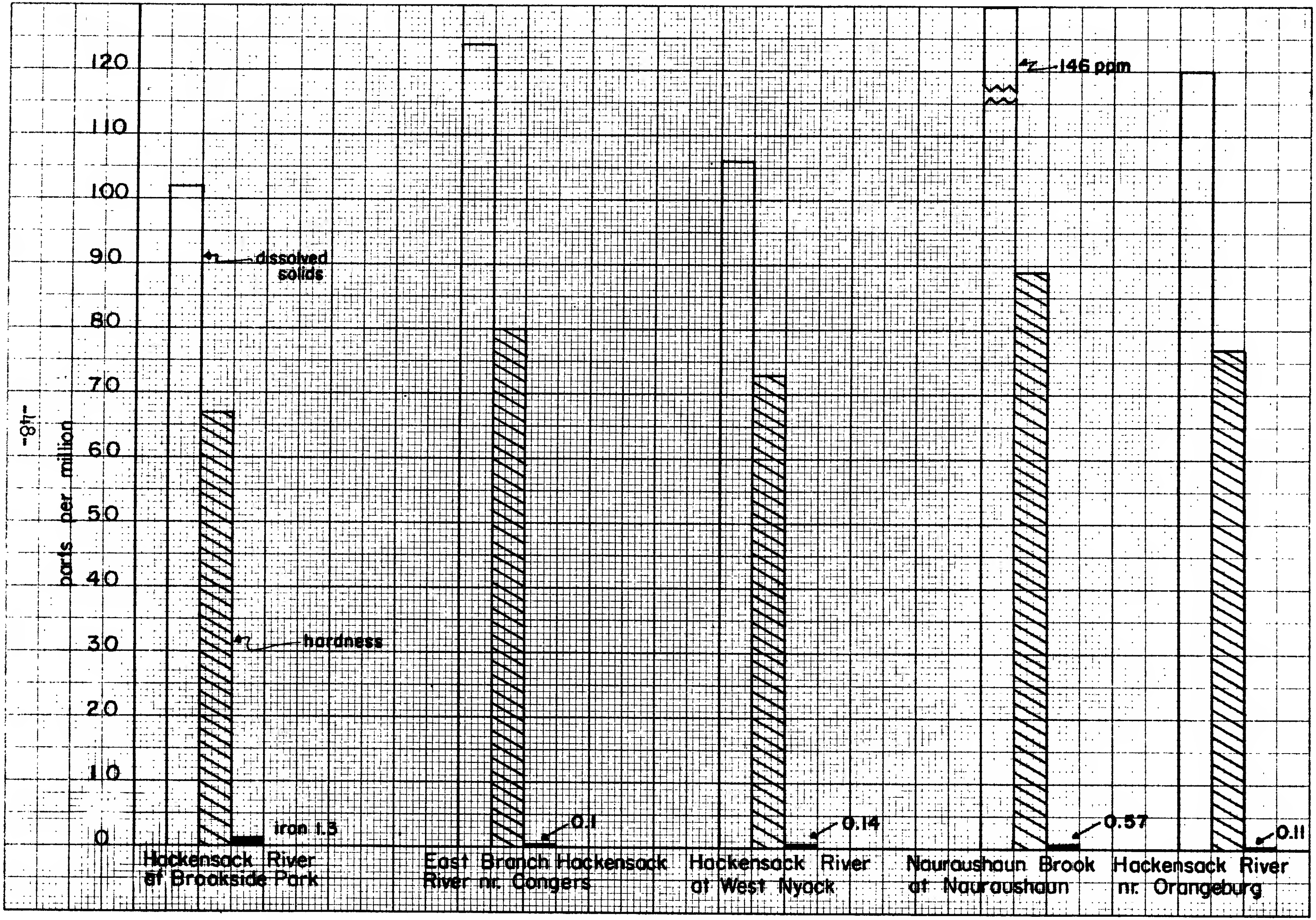


Fig. 16 Selected chemical characteristics and constituents of streams in the Hackensack River basin, December 3, 1959

Because hardness of water is due, for the most part, to concentrations of calcium and magnesium, any change in the concentrations of these constituents will in turn affect the hardness of water. In water from Hackensack River at Brookside Park the range in hardness was from soft to moderately hard - 52 to 78 ppm (table 14). Again the lower hardness was determined for a water sample collected during high flow - 151 cfs. When stream discharge dropped to about 6.2 cfs, hardness of water was increased to 78 ppm. In each of the water samples, the concentrations of calcium and magnesium were reduced as streamflow increased and conversely as streamflow decreased. The use of the water from Hackensack River would determine whether or not hardness would be a problem. For domestic use the problem, if any, would be insignificant.

Iron concentrations could well be a problem. In one sample, the iron concentration was 1.3 ppm. This was more than in any of the water samples collected at the downstream locations or from the tributaries. Such a concentration of iron in water would be very troublesome, causing staining and deposition. This high iron concentration was determined in a water sample collected during moderate flow - 16 cfs. Presumably at lower flows high or higher concentrations of iron would be in solution. Additional information is necessary to determine the fluctuations of iron concentrations in water from Hackensack River with streamflow.

On the basis of chemical quality, water from the Hackensack River could be used for most purposes. The mineral content is moderate and, generally, hardness of water would not affect its utility. Iron could be a problem assuming that the iron concentration determined in one sample was characteristic of water from Hackensack River.

Suspended sediment in Hackensack River could be a problem, however. The maximum daily load of suspended sediment measured at Brookside Park during 29 days (1960-61) was 62 tons per day; this occurred on April 16, 1961. The range for the 29 days was 0.6 to 62 tons per day. The total load for the period was 255.8 tons, mostly silt and clay with a small percentage of sand (tables 15 and 16). Apparently a sizeable quantity of sediment is carried into DeForest Lake. How the sediment characteristics of Hackensack River vary with climatic conditions has not been defined because of the short period of record. However, such information would be desirable and further work is recommended.

East Branch Hackensack River at Congers

This principal tributary rises in Rockland Lake at an elevation of 149 feet. The lake (28 acres) drains a small area ranging in elevation up to 620 feet, and drains rather sluggishly northward to Swartwout Lake, which in turn discharges westward to Congers Lake. From the south end of Congers Lake, East Branch Hackensack River flows south and then west along Old Mill Road to DeForest Lake.

Table 15. - Suspended sediment, Hackensack River at Brookside Park

		Suspended Sediment				Suspended Sediment	
Date	mean discharge (cfs)	mean concentration ppm	tons per day	Date	mean discharge (cfs)	mean concentration ppm	tons per day
Nov. 1, 1960	60	18	a 4	Apr. 15, 1961	46	--	e 0.6
Feb. 23, 1961	117	20	a 6	16	170	71	s62
24	98	16	a 4	17	131	39	s18
25	166	--	e14	18	104	26	s 8.4
26	314	35	sa35	19	105	17	4.8
Mar. 14	125	32	s12	May 7	58	19	s 3.2
15	103	14	3.9	10	51	25	3.4
16	98	9	2.4	26	17	13	.6
24	86	22	5.1	June 11	26	52	s 4.2
25	72	12	2.3	July 20	15	34	s 1.6
Apr. 10	49	40	sa 6	24	40	90	s20
11	48	20	2.6	25	68	71	s16
12	35	--	e .9	Aug. 23	20	46	s 2.7
13	87	30	sa 8	24	12	21	.7
14	83	14	s 3.4				

a Computed from partly estimated concentration graph.

e Estimated.

s Computed by subdividing day.

Table 16. - Particle size analyses of suspended sediment

in streams in Rockland County

(Method of analysis: B, Bottom withdrawal tube; N, Native water; W, in distilled water; C, Chemically dispersed; M, Mechanically dispersed)

Streams and Location	Site No	Date of Collection	Time	Instantaneous discharge (cfs)	Concentration of sample ppm	Concentration of suspension analyzed ppm	Suspended Sediment Percent finer than indicated size in millimeters										Method of Analysis
							Clay		Silt				Sand				
							.002	.004	.008	.016	.031	.061	.125	.25	.50	1.0	
Hackensack River at Convent Rd. Bridge near Orangeburg	1A	10-24-1959	3:45 pm	160	22	522	37	50	60	77	86	95	97	98	99	100	BWCM
		2-11-1960	3:00 pm	240	54	1270	28	40	53	74	86	96	98	99	100	--	BWCM
Hackensack River, Rt. #304 at Brookside Park	3	7-24-1961	--	--	355	2120	--	64	75	88	95	97	98	100	--	--	BWCM
Nauraushaun Brook at Blauvelt Rd., near Nauraushaun	4	10-24-1959	4:05 pm	84	31	1030	38	46	55	61	66	72	74	77	100	--	BWCM
		2-11-1960	3:20 pm	--	63	1660	22	30	35	50	65	79	82	98	100	--	BN

At a point about 0.7 mile upstream from the mouth of East Branch, a partial-record station (drainage area 6.86 square miles) was established on Sept. 25, 1959. Since that date 11 discharge measurements have been made, six of them under baseflow conditions. The results of the measurements appear in Table 17.

Because the flow during water years 1960 and 1961 was higher than average with no appreciable periods of extreme low flow, no discharge measurements have been obtained to define the low end of the duration curve.

With the increase in residential development and its expanded system of streets and other paved areas, it is probable that a higher percentage of rainfall will run off this drainage area and somewhat sharper peaks can be anticipated than at present.

Water from East Branch Hackensack River contains more mineral matter and is slightly harder than that from Hackensack River (table 14 and fig. 16). During low flow (about 0.2 cfs), the dissolved-solids content was about 150 ppm and the hardness was 109 ppm. At higher flows, the chemical quality was comparable to that of Hackensack River at Brookside Park.

The iron concentration in a water sample from East Branch Hackensack River at Congers was less than that of the main stem at Brookside Park, 0.10 ppm in comparison with 1.3 ppm in a water sample (same date) from Hackensack River at Brookside Park (table 14). At the time of sample collection, the instantaneous discharge was 14 cfs. Whether iron concentration would increase as stream discharge decreases is not known.

Table 17. - Summary of Discharge Measurements, East Branch Hackensack River near Congers

Date	Discharge (cfs)	Date	Discharge (cfs)
Sept. 25, 1959	0.20	May 27, 1960	4.85
Nov. 8, 1959	19.6	Sept. 27, 1960	6.62
Mar. 21, 1960	12.7	Sept. 21, 1961	7.76
Mar. 30, 1960	7.95	Oct. 6, 1961	1.26
Mar. 31, 1960	27.4	Mar. 20, 1962	17.2
Apr. 5, 1960	59.2		

On the basis of available chemical quality information, water from East Branch Hackensack River would be satisfactory for most uses.

DeForest Lake, with a surface area of 985 acres, has a highly significant effect on flows in the lower reaches of Hackensack River. At the southern end of this lake there is a concrete dam with spillway elevation at 85 feet. One 12-inch and one 24-inch Howell Bunger valve in the lower part of the dam permit release of water into the river. The license granted by the New York State Water Power and Control Commission for the construction of the dam and reservoir requires a continuous release to provide not less than 9.75 mgd at a point just above the intake of the Nyack Water Company downstream. There are at present no facilities for diversion from the reservoir, but representatives of the Spring Valley Water Works and Supply Company have indicated that plans were under way for a filtration plant and water mains to feed reservoir water into the company's distribution system at some time in the near future.

Hackensack River at West Nyack

A gaging station is operated and maintained under a cooperative agreement with the Village of Nyack, at a point one mile downstream from DeForest Lake. This site is just a few feet upstream from a point where the Village of Nyack pumps an average of 1.6 mgd from the river for municipal water supply. The continuous record of flow at this station represents the total released or spilled from the reservoir upstream augmented by inflow from the intervening area between the reservoir and the gage, and decreased by that water diverted for public supply by the Village of Nyack.

The flow during the period of record has varied from a minimum daily of 10 cfs to a maximum of 654 cfs with an average of 52 cfs (table 18). Duration curves (fig. 17) show that flows equal to or in excess of 15 cfs occurred about 80 percent of the time in 1960 and 86 percent of the time in 1961. During the same years a flow equal to or in excess of 100 cfs occurred 14 and 18 percent of the time, respectively. Because of the extensive regulation above the gage, it is impossible to adjust the duration data to a standard period. The duration curves, as presented, indicate the patterns of flow during the period of record as affected by present regulation and diversion. They should not be used to predict future flow patterns.

The chemical quality of water from the Hackensack River at West Nyack is comparable to that at Brookside Park (table 14). Based on specific conductance, the approximate range of dissolved-solids concentrations was from 106 to 119 ppm. The range of hardness was 69 to 82 ppm under varying streamflow conditions.

At West Nyack, water in the Hackensack River, for the most part, is that released from DeForest Lake. Water released from a reservoir is well mixed and the chemical quality is generally uniform, irrespective of flow. The available information on the chemical quality suggests such uniformity.

Table 18. - Summary of Streamflow, Hackensack River at West Nyack, 1958-61

Location.--Lat 41°05'44", long 73°57'52", on right bank 20 ft downstream from New York Central (West Shore) Railroad, 1,000 ft upstream from State Highway 59, 1 mile downstream from DeForest Lake, at West Nyack.

Drainage area.--29.4 sq mi.

Records available.--December 1958 to December 1961.

Gage.--Water-stage recorder and stop-log control. Datum of gage is 53.50 ft above mean sea level (levels by Hackensack Water Company).

Extremes.--1958-59: Maximum discharge during period December to September, 418 cfs Mar. 7 (gage height, 5.39 ft); minimum daily, 10 cfs Jan. 11-14.

1959-60: Maximum discharge during water year, 654 cfs Aug. 19 (gage height, 6.23 ft); minimum daily, 11 cfs July 19-22.

1960-61: Maximum discharge during water year, 558 cfs Feb. 26 (gage height, 5.92 ft); minimum daily, 10 cfs Aug. 17-20.

Remarks.--Records good. Flow regulated by DeForest Lake. Diversion above station for municipal water supply for Village of Nyack.

Monthly and yearly mean discharge, in cubic feet per second

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The Year
1959	-	-	20.7	30.6	49.2	66.7	65.8	25.8	32.8	14.5	14.3	21.6	-
1960	39.8	20.6	85.5	71.5	122	47.9	90.3	37.3	23.6	36.3	48.7	64.7	57.1
1961	35.1	46.5	39.5	44.8	119	151	119	65.0	26.0	42.6	13.5	39.6	61.4

Monthly and yearly runoff, in inches (unadjusted)

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The Year
1959	-	-	0.81	1.20	1.74	2.62	2.50	1.01	1.24	0.57	0.56	1.20	-
1960	1.56	0.78	3.35	2.81	4.48	1.88	3.43	1.46	0.90	1.42	1.91	2.45	26.43
1961	1.38	1.76	1.55	1.76	4.22	5.93	4.51	2.55	0.99	1.67	0.53	1.50	28.35

Peaks above a base not listed because of regulation by DeForest Lake.

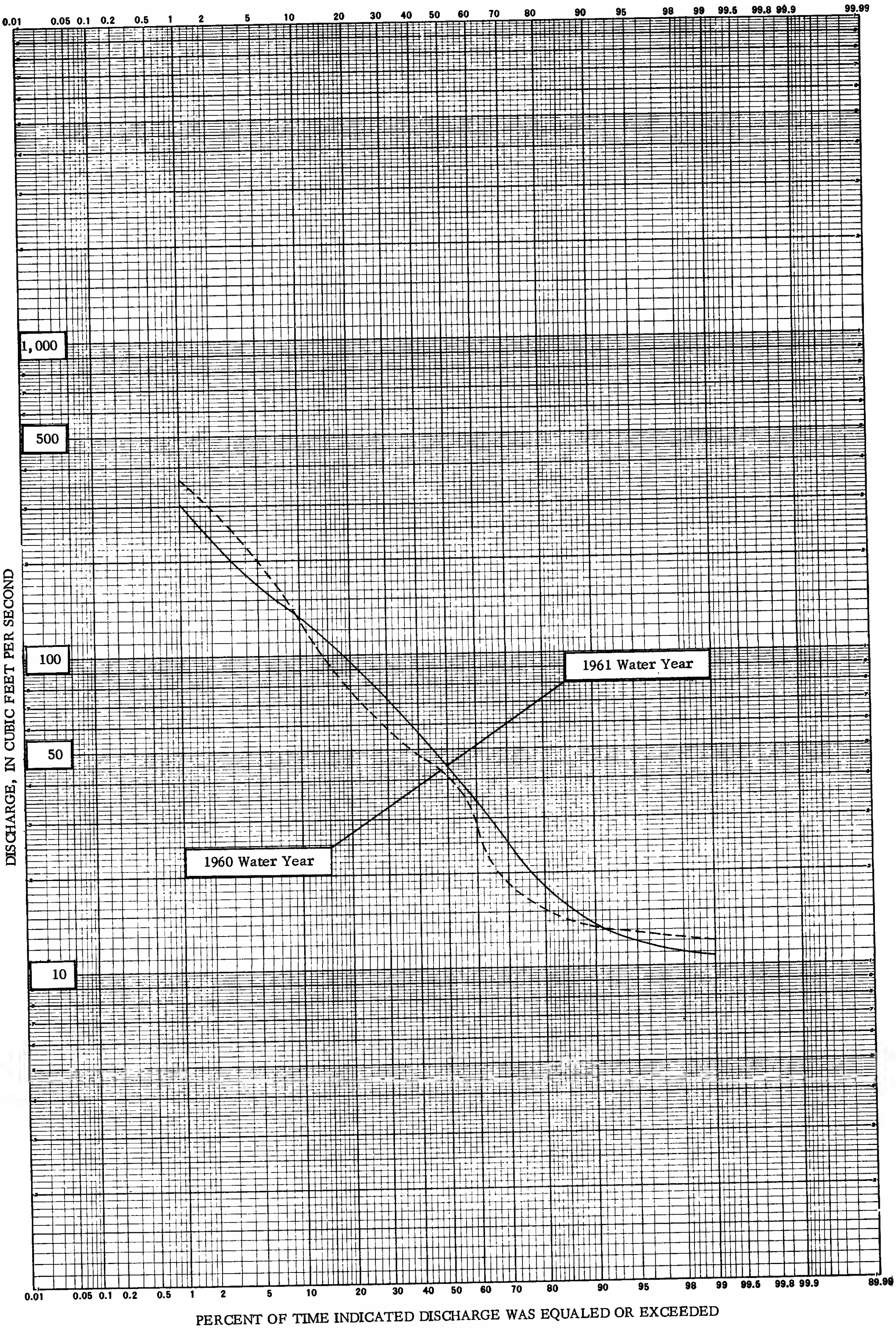


Figure 17. --Duration curves of daily flow, Hackensack River at West Nyack, N. Y.

The concentration of iron in water from the Hackensack River at West Nyack was less than that at Brookside Park. But, the concentration of manganese was slightly higher - 0.24 ppm at West Nyack and 0.04 ppm at Brookside Park. The combined concentrations of these two constituents could be troublesome, causing deposits and stains.

Hackensack River at Nauraushaun

Immediately below the West Nyack gage, Hackensack River flows through a series of fairly large swamp areas and receives the flow from three tributaries on the east side of the basin. The largest of these rises in Garrabraut Pond at an elevation of 450 feet and drains a sparsely inhabited portion of the Town of Clarkstown. The next largest tributary rises at the same elevation but drains a more densely populated area of Central Nyack.

At a point about three miles southwest of the West Nyack gage, Hackensack River is joined by the flow of Nauraushaun Brook flowing from the north. Just downstream from the mouth of this tributary, the flow during the period of record ranged from a minimum daily discharge of 13 cfs to an instantaneous maximum of 638 cfs (table 19). The average for the 1961 water year was about 89 cfs.

A duration curve for this site is available for the 1961 water year (fig. 18). Since it represents the results of considerable regulation it should not be used for predicting future flow patterns. The data cannot be adjusted for the probable flow pattern on a long-term basis. Note the smooth pattern of the curve which results from the high degree of regulation at West Nyack. During the 1961 water year a flow equal to or in excess of 15 cfs occurred 98 percent of the time and flow equal to or in excess of 150 cfs, 15 percent of the time.

The considerable amount of residential development, taking place above and below West Nyack, will increase the rate of runoff from rainfall. However, except for the danger of inundation of low-lying areas no serious flooding problems are anticipated.

The possibility of the construction of an additional dam and reservoir on Hackensack River a short distance south of the New York-New Jersey state line should be considered when an evaluation is made of best land usage for the area adjacent to the stream south of West Nyack.

Some variation has been noted in the chemical quality of the Hackensack River at Nauraushaun in comparison with that at upstream locations (table 14, fig. 16). In one water sample, the dissolved-solids content was 120 ppm (December 3, 1959). At the upstream locations on the same date, the dissolved-solids content in water samples collected at West Nyack was 106 ppm and in those collected at Brookside Park, it was 102 ppm. In other water samples (based on specific conductance), the dissolved-solids content was as high as 148 ppm.

Table 19. - Summary of Streamflow, Hackensack River at Nauraushaun, 1959-61

Location.--Lat 41°03'16", long 73°58'56", on left bank on downstream side of Convent Road bridge, just downstream from Nauraushaun Brook, at Nauraushaun, 1 1/2 miles upstream from New York-New Jersey State line, and 3 3/4 miles downstream from gaging station "at West Nyack".

Drainage area.--44.9 sq mi.

Records available.--December 1959 to December 1961.

Gage.--Water-stage recorder. Altitude of gage is 45 ft (from topographic map).

Extremes.--1959-60: Maximum discharge during period December to September, 638 cfs Aug. 19 (gage height, 6.09 ft); minimum daily 13 cfs July 25.
1960-61: Maximum discharge during water year, 540 cfs Feb. 27 (gage height, 5.79 ft); minimum daily, 13 cfs Sept. 13,14.

Remarks.--Records good. Flow regulated by DeForest Lake. Diversion above station by Village of Nyack for water supply.

Monthly and yearly mean discharge, in cubic feet per second

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The Year
1960	-	-	130	109	166	76.5	124	57.0	27.1	52.9	81.1	99.0	-
1961	51.5	70.3	66.3	77.9	175	211	176	89.5	36.3	56.5	24.2	38.1	88.8

Monthly and yearly runoff, in inches (unadjusted)

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The Year
1960	-	-	3.34	2.79	3.98	1.96	3.07	1.46	0.67	1.36	2.08	2.46	-
1961	1.32	1.75	1.70	2.00	4.07	5.42	4.38	2.30	0.90	1.45	0.62	0.95	26.86

Peak discharge (base, 400 cfs)

Date	Time	Gage Height (ft)	Discharge (cfs)	Date	Time	Gage Height (ft)	Discharge (cfs)
2-12-60	7:30 pm	4.98	420	9-12-60	3:00 pm	5.62	544
4-6-60	5-6 pm	4.97	418	2-27-61	1:00 pm	5.79	540
7-30-60	12 noon	4.92	409	4-16-61	4:00 pm	5.59	500
8-19-60	10:00 am	6.09	638				

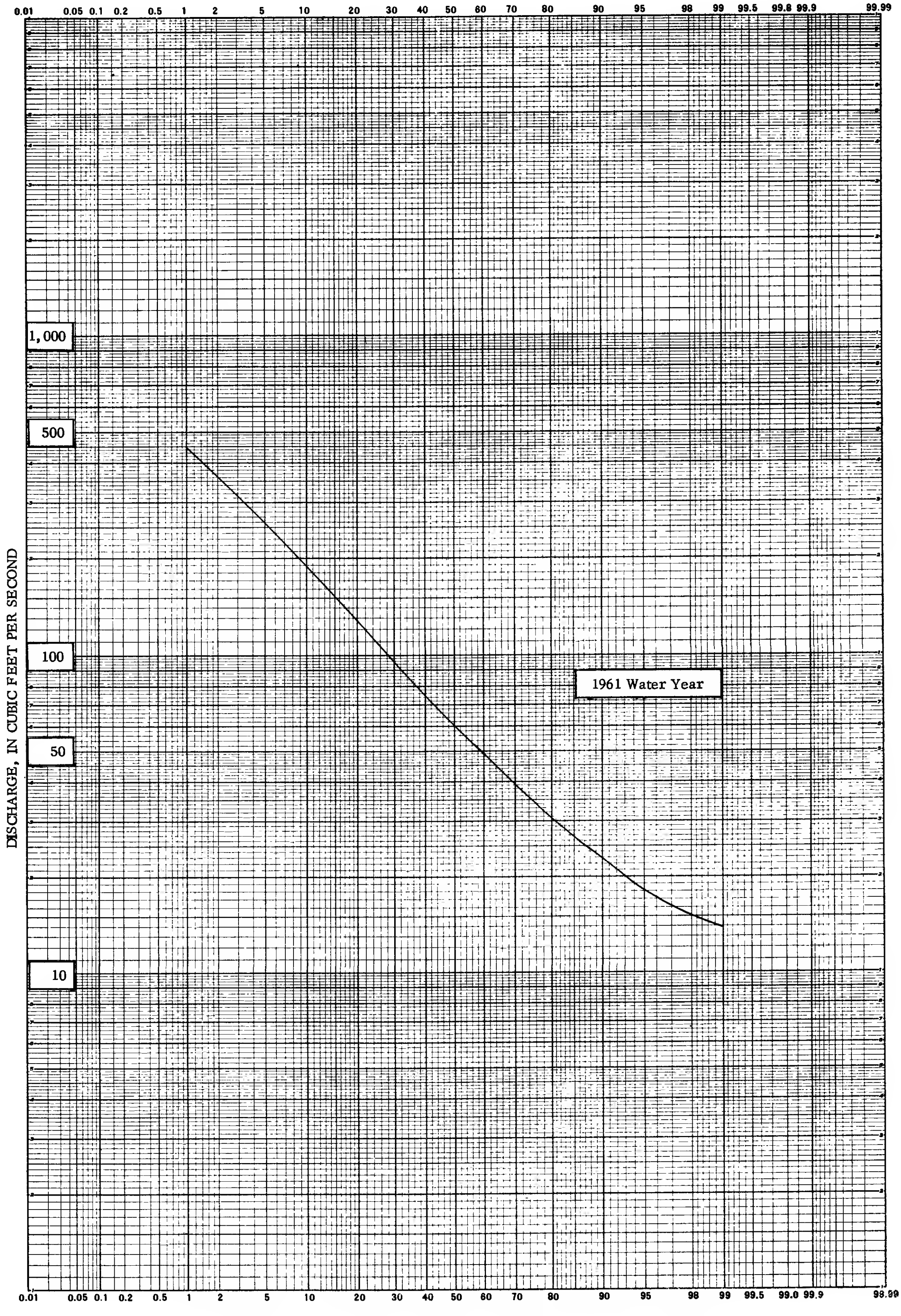


Figure 18.--Duration curve of daily flow, Hackensack River at Nauraushaun, N. Y.

Hardness of water from the Hackensack River at Nauraushaun was also slightly higher than that at upstream locations. This increase is apparently due to the inflow of water from Nauraushaun Brook. As a matter of fact, on two different days (July 12 and August 31, 1961 when streamflow was low), the hardness of water from Nauraushaun Brook and Hackensack River was the same (table 14).

Based on the chemical quality, water from the Hackensack River at Nauraushaun would be satisfactory for many purposes. The dissolved-solids content was moderate and the water was moderately hard. Iron and manganese concentrations were low. Concentrations of other constituents would not affect adversely the utility of the water.

Nauraushaun Brook at Nauraushaun

This Brook has its source at an elevation of 440 feet, north of Oak Brook, and flows south for about two miles to a point just north of Nanuet. The area drained to this point is principally swamp land, closely adjacent to areas which are being urbanized rapidly. Just north of Nanuet the stream flows east and then south for an additional mile. It then turns eastward at a point where it is joined by a major tributary from the north and a smaller tributary from the south, both draining well-urbanized areas. After flowing a short distance east, the stream once again heads southward through Martins Lake and 1 1/4 miles of rapidly urbanizing area to Blauvelt Road.

As shown in table 20, the minimum flow for 1960 was 0.4 cfs and for 1961, 0.1 cfs. The average flow during the 1961 water year was 10.6 cfs, equivalent to nearly 7 mgd.

During the 1961 water year the flow was equal to or in excess of 1 cfs, 96 percent of the time and equal to or in excess of 29 cfs, 10 percent of the time (fig. 19). The shape of the duration curve indicates fairly high flood-producing potential and relatively poor low-water yield.

Water from Nauraushaun Brook contains more dissolved solids and is slightly harder than that of other tributaries or the main stem in the Hackensack River basin (table 14). In one water sample, the dissolved-solids content was 146 ppm and the hardness was 89 ppm. The dissolved-solids concentration of water from Nauraushaun Brook was higher than that of most of the other water samples collected in the basin. Hardness concentrations as high as 96 ppm were determined for water samples collected during low-flow periods.

Mention has already been made that the chemical quality of Nauraushaun Brook influences the chemical quality of Hackensack River downstream, particularly during low-flow periods. If the water from Nauraushaun Brook were used as source of water supply for public or industrial use treatment would be required to reduce the hardness. Treatment would also have to be applied to reduce the iron concentration, and that of manganese. In one sample, the iron concentration was 0.57 ppm and the manganese was 0.19 ppm. What the variation would be seasonally with fluctuating streamflow conditions is not known. However, the data suggest a possibility that iron and manganese could, at times, affect the utility of water from Nauraushaun Brook.

Table 20. - Summary of Streamflow, Nauraushaun Brook at Nauraushaun, 1960-61

Location.--Lat 41°03'42", long 73°59'41", on left bank at bridge on Blauvelt Road, at Nauraushaun, and 3/4 mile upstream from mouth.

Drainage area.--6.08 sq mi.

Records available.--February 1960 to September 1961.

Gage.--Water-stage recorder. Altitude of gage is 95 ft (from topographic map). Staff gage Feb. 10 to Apr. 28, Aug. 21 to Oct. 11, 1960. Prior to Apr. 29, 1960, crest-stage gage.

Extremes.--1959-60: Maximum discharge recorded during period February to September, 413 cfs Sept. 12 (gage height, 4.00 ft); minimum recorded 0.4 cfs June 17.

1960-61: Maximum discharge observed during water year, about 1,300 cfs Aug. 19, 1960 (gage height, 5.3 ft from flood marks); minimum, 0.1 cfs June 21.

Remarks.-- Records poor. Some regulation by ponds and reservoirs above station.

Monthly and yearly mean discharge, in cubic feet per second

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The Year
1960	-	-	-	-	29.8	10.5	19.6	7.46	2.32	8.73	13.4	15.2	-
1961	6.28	8.96	5.94	7.00	20.8	25.3	22.9	11.9	3.69	6.67	4.56	3.71	10.6

Monthly and yearly runoff, in inches

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The Year
1960	-	-	-	-	5.29	1.99	3.60	1.42	0.43	1.65	2.54	2.79	-
1961	1.19	1.64	1.13	1.33	3.56	4.79	4.21	2.06	0.68	1.26	0.87	0.68	23.60

Peak discharge (base, 180 cfs)

Date	Time	Gage Height (ft)	Discharge (cfs)	Date	Time	Gage Height (ft)	Discharge (cfs)
2-19-60	Unknown	3.02	185	8-19-60	Unknown	5.3	1,300
7-30-60	9:30 am	3.41	262	9-12-60	about 6 pm	4.0	413

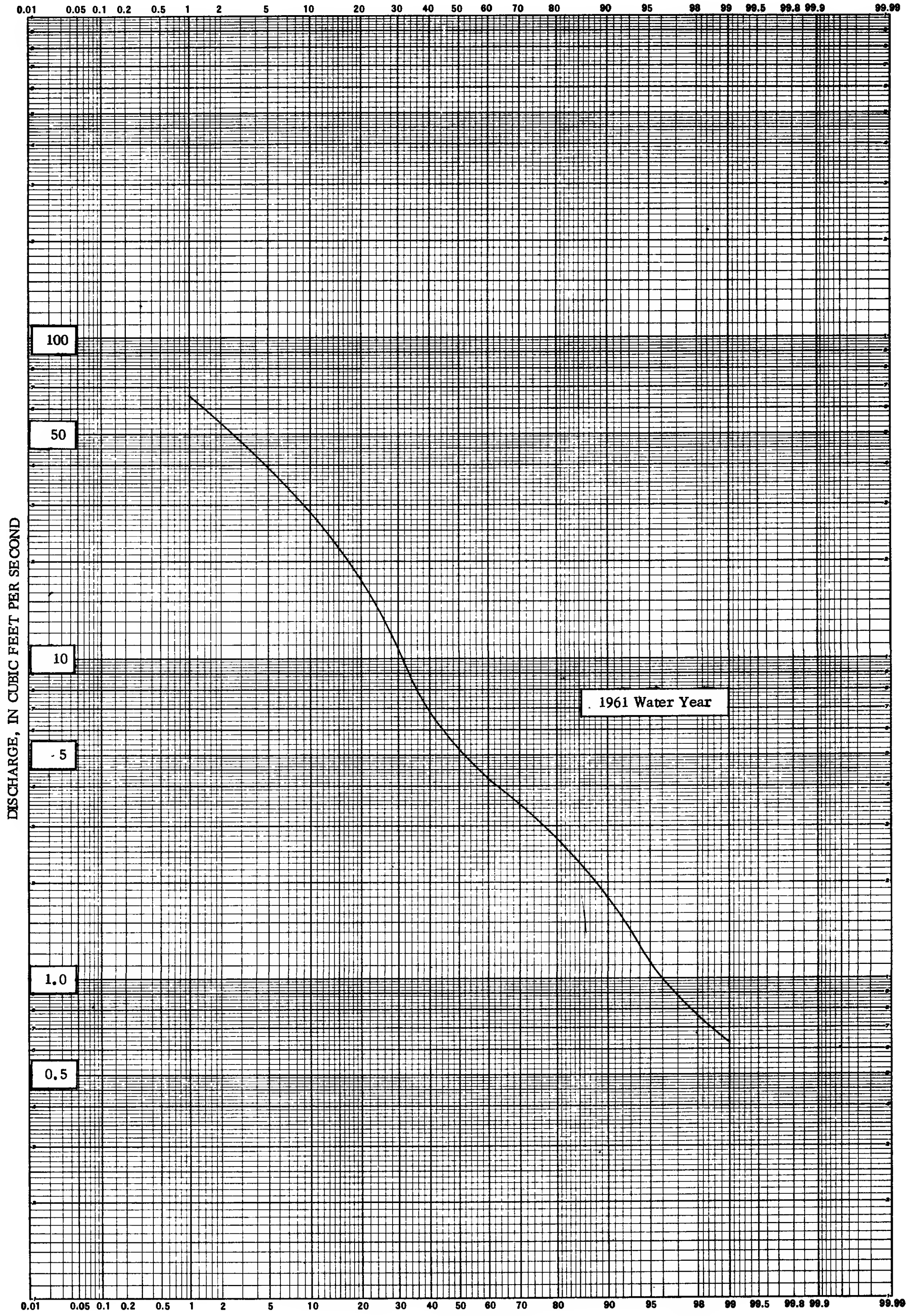


Figure 19.--Duration curve of daily flow, Nauraushaun Brook at Nauraushaun, N. Y.

PASCACK BROOK BASIN

Pascack Brook drains an area of 10.5 square miles in Rockland County. Parts of the area are highly urbanized and other parts are rapidly approaching a highly urbanized state. It is estimated that 70-80 percent of the basin was urbanized at the end of 1961. Included in the basin are all of the Village of Spring Valley and a small part of Pearl River.

The main branch of Pascack Brook rises north of Hillcrest, Town of Ramapo. It flows in a southerly direction for about 3 1/2 miles to a point southeast of Spring Valley, flows east of the Spring Valley Sewage Treatment Plant (effluent from the plant is discharged into the Brook), and just below Route 59, is joined by a major tributary from the northwest.

Pascack Brook Tributary at Spring Valley

This portion of Pascack Brook (4.58 square miles) rises in the Town of Ramapo, just east of the Village of Viola, at an elevation of 590 feet, in an orchard area. One small branch has its source in a swamp area, a short distance east, and another branch in a larger swamp directly north of Spring Valley. The major branch, flowing easterly through several sizeable ponds, joins the other branches at the northern boundary of Spring Valley. The tributary so formed then flows southeasterly along the eastern boundary of the Village of Spring Valley and through several ponds with man-made outlet structures. It joins Pascack Brook near Route 59.

Records of flow past the gaging station 100 feet upstream from the mouth show a high degree of regulation. This condition is the result of recreational use, for which purposes ponds and small lakes in the basin are filled and emptied from time to time. The records also include an undetermined amount of storm-water runoff during periods of heavy rainfall.

The maximum flow recorded at this site was 378 cfs in 1960 and 148 cfs in 1961 (table 21). The 1960 minimum daily flow was 0.1 cfs. During one day in 1961 due to man-made regulation upstream no flow passed the gage.

Considerable variation between the two curves in figure 20 is clearly evident. Both have the same low-end characteristic, that of extremely poor yield below the 98 percent point or for about one week each year. This condition is undoubtedly the result of the filling of ponds and swimming pools upstream from the gage. Flow equal to or in excess of 20 cfs occurred about 6 percent of the time each year.

This tributary has a limited potential as a source of water. Its principal use will continue to be for recreational purposes. Perhaps this is its best use because water from the tributary contains fairly high concentrations of dissolved solids, and its hardness ranges from moderately hard to hard.

Table 21. - Summary of Streamflow, Pascack Brook Tributary at Spring Valley, 1959-61

Location.--Lat 41°06'15", long 74°01'57", on right bank 100 ft upstream from mouth and 150 ft downstream from bridge on Pascack Road at Spring Valley.
Drainage area.--4.58 sq mi.
Records available.--October 1959 to December 1961.
Gage.--Water-stage recorder. Altitude of gage is 345 ft (from topographic map).
Extremes.--1959-60: Maximum discharge during water year, 378 cfs Aug. 19 (gage height, 4.46 ft); minimum daily, 0.1 cfs May 29.
1960-61: Maximum discharge during water year, 148 cfs Apr. 16 (gage height, 3.46 ft); minimum daily, no flow June 9.
Remarks.--Records fair. Regulation from upstream mills and ponds.

Monthly and yearly mean discharge, in cubic feet per second

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The Year
1960	4.37	4.39	8.64	8.56	11.7	7.36	12.4	5.86	3.49	7.40	9.07	10.3	7.78
1961	5.78	4.41	3.65	3.92	11.8	16.2	15.7	10.4	4.37	5.41	3.63	2.84	7.31

Monthly and yearly runoff, in inches (unadjusted)

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The Year
1960	1.10	1.07	2.18	2.15	2.76	1.85	3.01	1.48	0.85	1.86	2.28	2.52	23.11
1961	1.45	1.07	0.92	0.99	2.69	4.08	3.81	2.63	1.06	1.36	0.91	0.69	21.66

Peak discharge (base, 95 cfs)

Date	Time	Gage Height (ft)	Discharge (cfs)	Date	Time	Gage Height (ft)	Discharge (cfs)
1-3-60	11:30 am	3.39	136	8-19-60	12:30 pm	4.46	378
7-3-60	11:30 pm	3.17	103	9-12-60	3:30 pm	4.00	255
7-27-60	9:00 pm	3.12	96	2-26-61	1:30 am	3.40	138
7-30-60	12:30 pm	3.78	208	4-16-61	5:00 pm	3.46	148

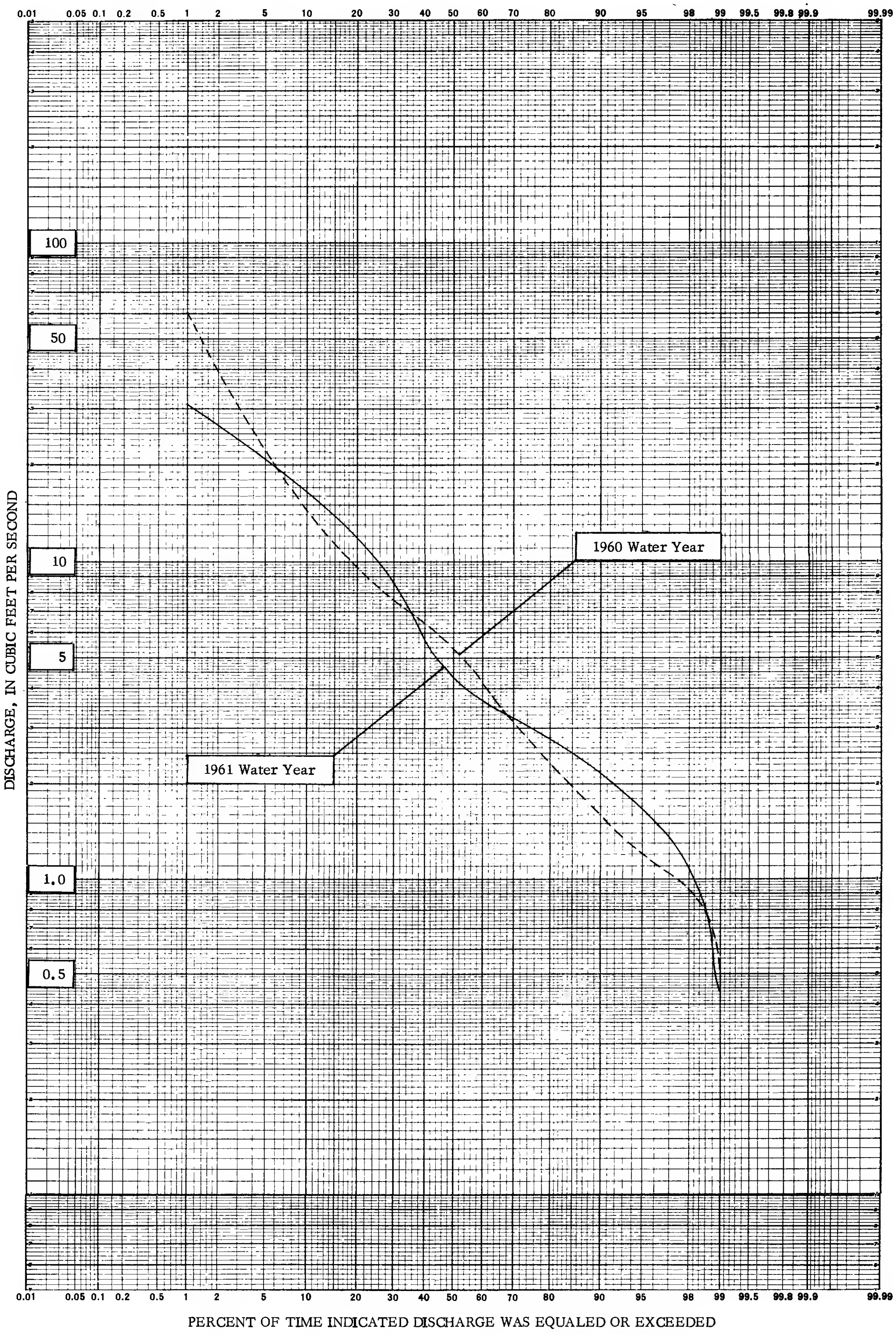


Figure 20.--Duration curves of daily flow, Pascack Brook Tributary at Spring Valley, N.Y.

Table 22. - Chemical analyses of streams

in the Pascack Brook basin

(parts per million)

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Date of collection	Discharge (cfs)	Water temperature (°F)	Silica (SiO$_2$)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO$_3$)	Sulfate (SO$_4$)	Chloride (Cl)	Fluoride (F)	Nitrate (NO$_3$)	Dissolved solids	Hardness as CaCO$_3$		Specific conductance (micromhos at 25°C)	pH	Color
																Ca, Mg	Non-carbonate			
Pascack Brook at Spring Valley																				
July 1, 1957		66	9.4	0.20	0.36	42	11	7.6	2.0	130	34	14	0.1	9.3	208	150	44	331	7.0	7
April 8, 1958		--	5.1	.70	.07	13	2.8	3.0	.8	26	21	3.9	.1	3.0	80	44	23	113	6.3	17
Pascack Brook at Pearl River																				
Aug. 31, 1959		71								91						106		304	7.2	
Dec. 3	10	42	11	.34	.19	34	7.8	11	2.5	92	34	14	.2	15	179	117		300	7.9	6
Feb. 11, 1960	39	45								58						82		212	6.5	
July 12	6.6	74								108						122		314	7.3	
Oct. 20	36	57		.28						77					145	96		235	6.8	
Aug. 31, 1961	6.6	74								116						133		360	7.1	
Tributary to Pascack Brook, Spring Valley																				
Sept. 1, 1959		76								104						100		228	7.5	
Dec. 3	3.6	41	8.0	.33	.06	31	8.0	5.7	1.8	96	33	8.1	.1	5.2	155	111	32	264	7.3	16
Feb. 11, 1960	42	42								73						91		220	6.7	
July 12	1.7	79								102						146		229	7.4	
Aug. 31, 1961	2.4	80								104						113		247	7.2	

One water sample from the tributary had a dissolved-solids content of 155 ppm and the hardness was 111 ppm, a moderately hard water (table 22). This sample was collected when streamflow was 3.6 cfs. At lower discharges, the hardness of water from the tributary was still higher, as high as 146 ppm.

Perlmutter (1959, P. 42) reports that the rocks in the area contain pebbles of limestone. Ground-water flow and streamflow drained from these rocks account for the chemical composition of the water in the tributary. It consists principally of calcium, bicarbonate and sulfate. This is characteristic of the Pascack Brook basin. Particularly during low flow, ground water is the major component of streamflow. Thus, the concentrations of dissolved solids and particularly hardness are higher than at other times when dilution by surface runoff is greater.

Because the chemical composition of water from the tributary is one of calcium and bicarbonate, the water is alkaline. In the samples collected, the pH was above 7.0, except for one water sample (table 22). On the basis of geology, the chemical quality can be expected to be one of moderate dissolved solids and ranging in hardness from moderately hard to hard.

In one water sample, the iron concentration was 0.33 ppm and that of manganese 0.06 ppm. The iron and manganese could be a problem, causing deposits and stains. Perlmutter reports iron oxide is a coating on mineral grains in the area. Iron concentrations of magnitude cited above and higher can be expected in water from the tributary to Pascack Brook.

Pascack Brook at Pearl River

At Pearl River, the flow in Pascack Brook consists of that of the tributary described in the preceding section, the effluent from the Spring Valley Sewage Treatment Plant, and intervening-area contribution. The effluent is discharged at a varying rate but during 1960-61 the average was about 1.7 mgd.

The range in discharge at Pearl River was from 1.6 to 800 cfs (table 23). During 1961, 99 percent of the time the discharge in Pascack Brook equalled or exceeded 5.6 cfs and only 10 percent of the time did discharge equal or exceed 45 cfs. During 1960, the discharge for the same percentages of time was lower (fig. 21). The addition of sewage is effective in modifying natural streamflow conditions, particularly during low flow.

As was the case for Sparkill Creek (fig. 12), the minimum average daily water temperatures occurred during the winter months when air temperatures were lowest and the maximum during July and August when the average daily air temperatures at Suffern were highest (fig. 22).

Figure 23 is a plot of daily variations during the months of October and November 1960, and July and August 1961 of water temperatures in Pascack Brook at Pearl River and air temperatures at the Suffern Water Works. Note the small variation in daily water temperatures as compared to air temperatures.

Table 23. - Summary of Streamflow, Pascack Brook at Pearl River, 1959-61

Location.--Lat 41°03'35", long 74°02'11", on left bank 150 ft upstream from Washington Avenue bridge, at Pearl River, and 1/4 mile upstream from New York-New Jersey State line.

Drainage area.--10.2 sq mi.

Records available.--September 1959 to December 1961.

Gage.--Water-stage recorder. Altitude of gage is 220 ft (from topographic map).

Extremes.--1959: Minimum discharge during September, 3.2 cfs Sept. 17.
1959-60: Maximum discharge during water year, 800 cfs Aug. 19 (gage height, 8.50 ft); minimum, 3.5 cfs Oct. 5,6.
1960-61: Maximum discharge during water year, 288 cfs Feb. 25 (gage height, 6.48 ft); minimum, 1.6 cfs May 15.

Remarks.--Records good. Discharge includes about 2.5 cfs of effluent from Spring Valley sewage disposal plant. Water temperature since December 1959.

Monthly and yearly mean discharge, in cubic feet per second

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The Year
1960	13.9	13.2	23.4	22.5	31.5	17.7	28.9	14.7	8.47	17.2	23.6	26.9	20.1
1961	13.1	14.1	10.8	13.4	34.8	45.7	42.6	24.3	13.5	16.0	10.6	10.5	20.7

Monthly and yearly runoff, in inches (unadjusted)

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The Year
1960	1.57	1.45	2.65	2.54	3.33	2.00	3.16	1.66	0.93	1.94	2.67	2.94	26.84
1961	1.48	1.54	1.23	1.51	3.55	5.17	4.66	2.75	1.48	1.81	1.20	1.15	27.53

Peak discharge (base, 175 cfs)

Date	Time	Gage Height (ft)	Discharge (cfs)	Date	Time	Gage Height (ft)	Discharge (cfs)
12-29-59	4:00 am	6.00	182	9-12-60	3:30 pm	7.70	590
1-3-60	12 noon	6.25	235	2-25-61	12:00 pm	6.48	288
7-30-60	1:00 pm	6.60	317	4-16-61	4:45 pm	6.44	279
8-19-60	12:30 pm	8.50	800				

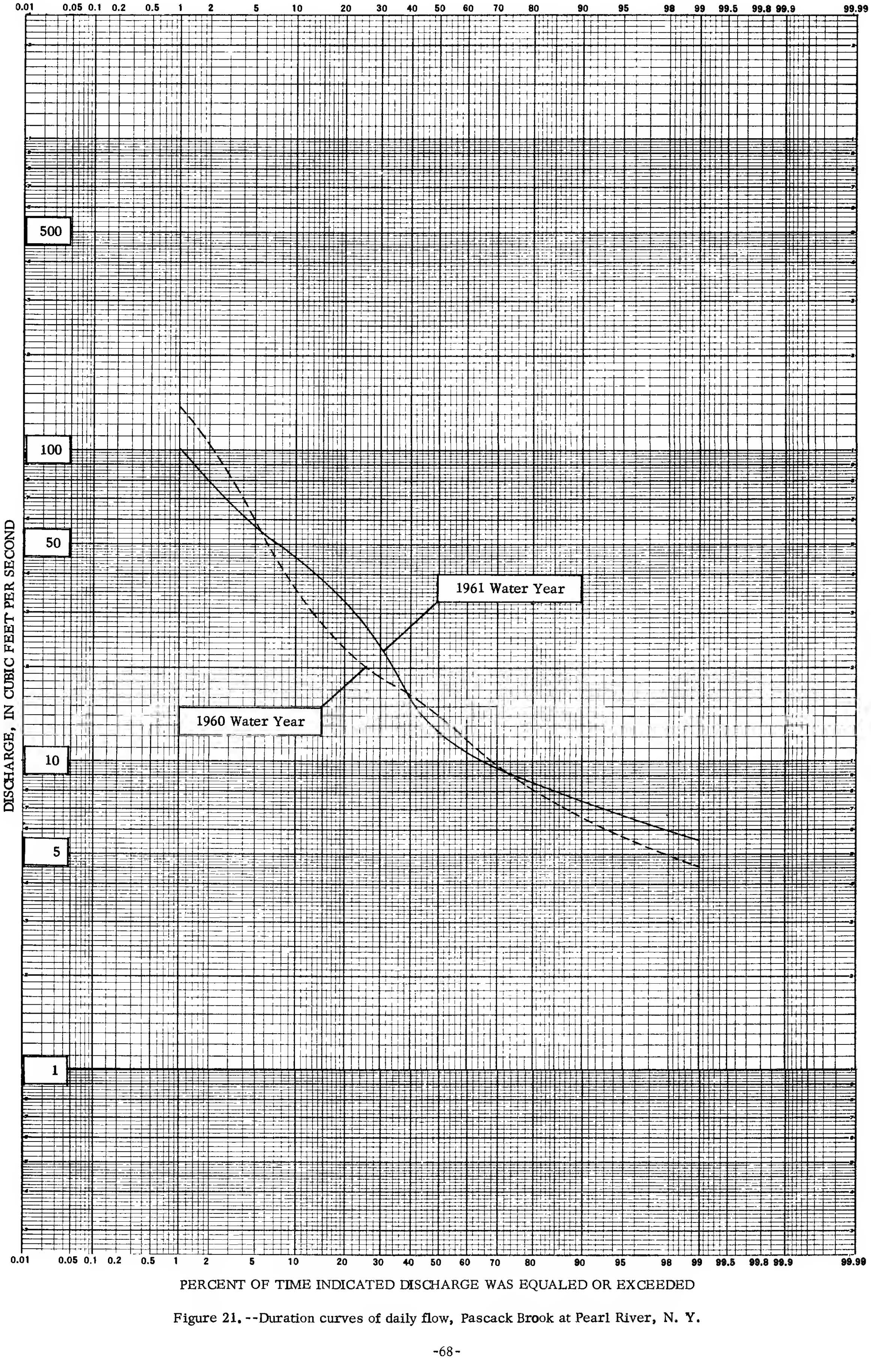

Figure 21.--Duration curves of daily flow, Pascack Brook at Pearl River, N. Y.

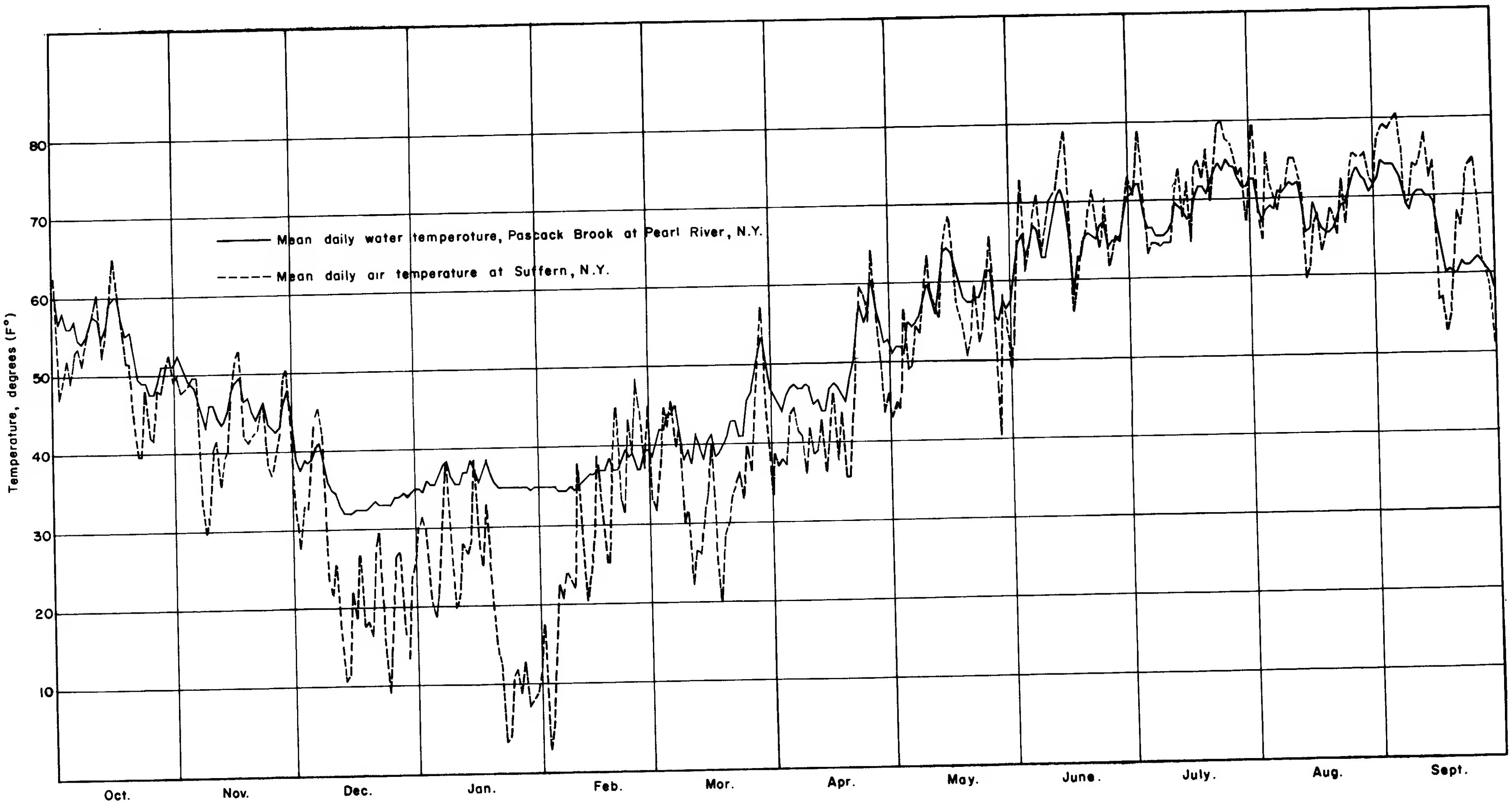

Figure 22.- Mean daily water temperature of Pascack Brook at Pearl River and air temperature at Suffern, 1961 Water Year.

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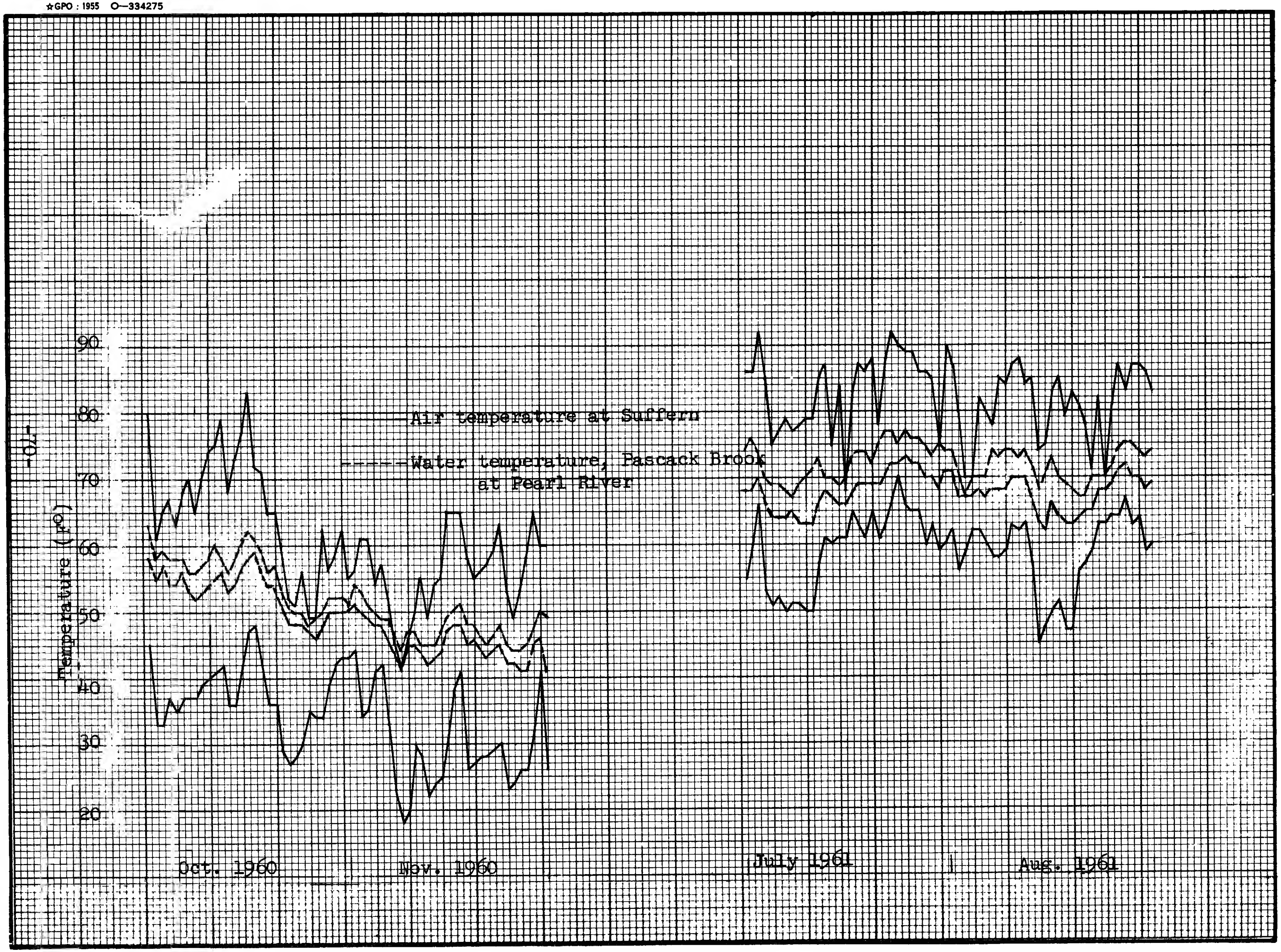

Figure 23.--Maximum and minimum water temperatures of Pascack Brook at Pearl River and air temperatures at Suffern, October - November 1960, and July - August 1961

Before considering the chemical quality of Pascack Brook at Pearl River, a review of the chemical quality upstream from the Sewage Treatment plant at Spring Valley would be helpful for comparison. Two analyses are available, one for a water sample collected during July 1957 (a period of low flow) and one of a sample collected during a period of high flow - April 8, 1958 (table 22). The effect of dilution is very striking. The low-flow sample had a dissolved-solids content of 208 ppm and was moderately hard - 150 ppm. But, the dissolved-solids content of the sample collected during high flow, dropped to 80 ppm, and the water was soft-hardness 44 ppm. The water from both samples had a chemical composition consisting mostly of calcium and bicarbonate.

The iron and manganese concentrations were sufficient in each sample to cause stains and deposition. But, the manganese concentration was higher than that of iron in the low-flow sample - manganese concentration was 0.36 ppm and that of iron 0.20 ppm. Conversely, in the high-flow sample, the iron concentration was higher than that of manganese, iron concentration was 0.70 ppm and that of manganese was 0.07 ppm. Immediately, several questions arise. Is the iron-manganese relationship in the two samples an isolated one? Does it occur often and, if so, under what conditions? On the basis of two water samples, no clues are given. The pH values and those of color are different for the two samples. Perhaps these are the conditions that account for the iron-manganese relationship. But, at present, no clear-cut answer has been found.

The chemical quality of Pascack Brook at Pearl River also fluctuated but within a narrower range. The range of dissolved solids (based on specific conductance) was about 145 to 250 ppm and that of hardness from 82 to 133 ppm. During 1959-61, water samples were collected during high and low flows. As at Spring Valley, the chemical composition consisted of calcium and bicarbonate. In one sample the combined concentration of iron and manganese was 0.53 ppm, of which the iron concentration was 0.34 ppm.

No attempt was made to determine the pollution in Pascack Brook. But contamination is apparent in the form of billowy globs of foam floating down the stream.

At Pearl River, Pascack Brook transported considerable suspended sediment during 1961. The range of sediment load was 0.2 to 120 tons per day. However, this range covered only 39 days (usually storm events) when sediment load was measured. The total load for the 39 days was 463 tons, mostly silt and clay with a small percentage of sand sizes (table 24).

Table 24. - Suspended sediment in Pascack Brook at Pearl River

		Suspended Sediment				Suspended Sediment	
Date	mean discharge (cfs)	mean concentration ppm	tons per day	Date	mean discharge (cfs)	mean concentration ppm	tons per day
Jan. 9, 1961	13	10	0.4	Apr. 17, 1961	74	88	s22
15	16	8	.3	18	90	--	c40
Feb.14	21	20	1.1	19	74	50	sb12
23	63	38	6.5	29	38	59	6.0
24	66	43	s 8.9	May 7	46	--	e 4
Mar. 9	42	18	2.0	27	28	30	sb 2
10	40	18	a 2	28	45	50	sb 8
11	31	18	a 2	29	18	13	.6
12	36	20	a 2	June 11	22	45	s 3
13	36	20	a 2	22	49	28	3.7
14	112	40	s40	July 15	51	100	s30
19	51	24	3.3	16	40	55	8.7
24	63	61	12	24	42	120	sb25
Apr.10	60	142	s28	25	63	86	s17
11	39	55	a 6	26	12	25	a .8
12	28	20	a 2	27	9.1	18	a .4
13	70	55	sb12	28	8.0	12	a .2
14	55	40	a 6	29	17	55	sb 2
15	33	15	a 1	Aug. 23	48	121	s20
16	123	211	s120				

a Computed from estimated concentration graph.
b Computed from partly estimated concentration graph.
e Estimated.
s Computed by subdividing day.

PASSAIC RIVER BASIN

Saddle River near Spring Valley

Only a small portion of the Saddle River Basin lies within Rockland County. Most of this basin, with a total drainage area of about 60 square miles, lies south of the County line within the State of New Jersey.

Saddle River has its source in the Town of Ramapo, just southeast of Monsey, at an elevation of about 600 feet. Rising as three separate branches, the entire flow forms a single stream just above Monsey Lake, 2/3 mile north of the New Jersey state line. By the time it leaves the lake, Saddle River drains 2.06 square miles.

The flow in Saddle River near Spring Valley for the period of record varied from a low of 0.3 cfs to a high of 404 cfs (table 25). The average for the 1961 water year was 3.46 cfs, equivalent to a runoff of about 23 inches.

Because of a large amount of natural storage in the basin, the range in average monthly flows as well as in average daily flows was relatively small. Further evidence of the narrow range in the magnitude of flow of this stream is presented by the duration curve for the 1961 water year (fig. 24). A flow equal to or in excess of 1.5 cfs occurred 80 percent of the time while only 12 percent of the time was it equal to or in excess of 7 cfs.

The chemical quality of Saddle River was similar to that of some of the streams in the Pascack Brook basin. The rock types of the south-central part of Rockland County are sandstone and shale with pebbles of limestone. The dissolved-solids content ranged from about 90 to 170 ppm (based on specific conductance measurements) and the hardness from 56 to 122 ppm (table 26). The minimum was determined in water samples collected during high flow and the maximum in a water sample collected during low flow. Iron and manganese concentrations were not as high as those determined in water samples collected in the Pascack Brook basin.

Pine Brook near Spring Valley

Pine Brook is one of the smaller named streams in Rockland County. The east branch rises just southwest of Spring Valley in the Town of Ramapo at an elevation of 490 feet, and flows southeast a short distance through a swamp area north and south of the New York State Thruway. The next mile is through a series of man-made ponds equipped with artificial spillways over a course of a mile until it is joined by the west branch. The west branch rises just north of the Thruway and west of the source of the east branch. It then flows almost due south for 1 1/2 miles until it joins the east branch.

Table 25. - Summary of Streamflow, Saddle River near Spring Valley, 1960-61

Location.--41°04'54", long 74°05'00", on right bank 100 ft upstream from Hillside Ave., 900 ft upstream from New York-New Jersey State line, and 2 1/2 miles southwest of Spring Valley.
Drainage area.--2.06 sq mi.
Records available.--July 1960 to December 1961.
Gage.--Water-stage recorder. Altitude of gage is 295 ft (from topographic map).
Extremes.--1960: Maximum discharge during July to September, 404 cfs Aug. 19 (gage height, 8.63 ft); minimum, 0.3 cfs July 7.
1960-61: Maximum discharge during water year, 72 cfs Apr. 16 (gage height, 6.98 ft); minimum, 0.5 cfs June 30.
Remarks.--Records good. Regulation, and possibly diversion above station from unknown source.

Monthly and yearly mean discharge, in cubic feet per second

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The Year
1960	-	-	-	-	-	-	-	-	-	3.13	3.42	3.69	-
1961	2.04	2.35	1.92	2.50	5.35	7.57	7.37	4.26	2.28	2.46	1.99	1.56	3.46

Monthly and yearly runoff, in inches

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The Year
1960	-	-	-	-	-	-	-	-	-	1.75	1.92	2.00	-
1961	1.14	1.27	1.07	1.40	2.70	4.24	3.99	2.39	1.23	1.38	1.11	0.85	22.77

Peak discharge (base, 75 cfs)

Date	Time	Gage Height (ft)	Discharge (cfs)	Date	Time	Gage Height (ft)	Discharge (cfs)
7-30-60	10:15 am	7.35	115	9-12-60	1:00 pm	7.55	145
8-19-60	9:00 am	8.63	404				

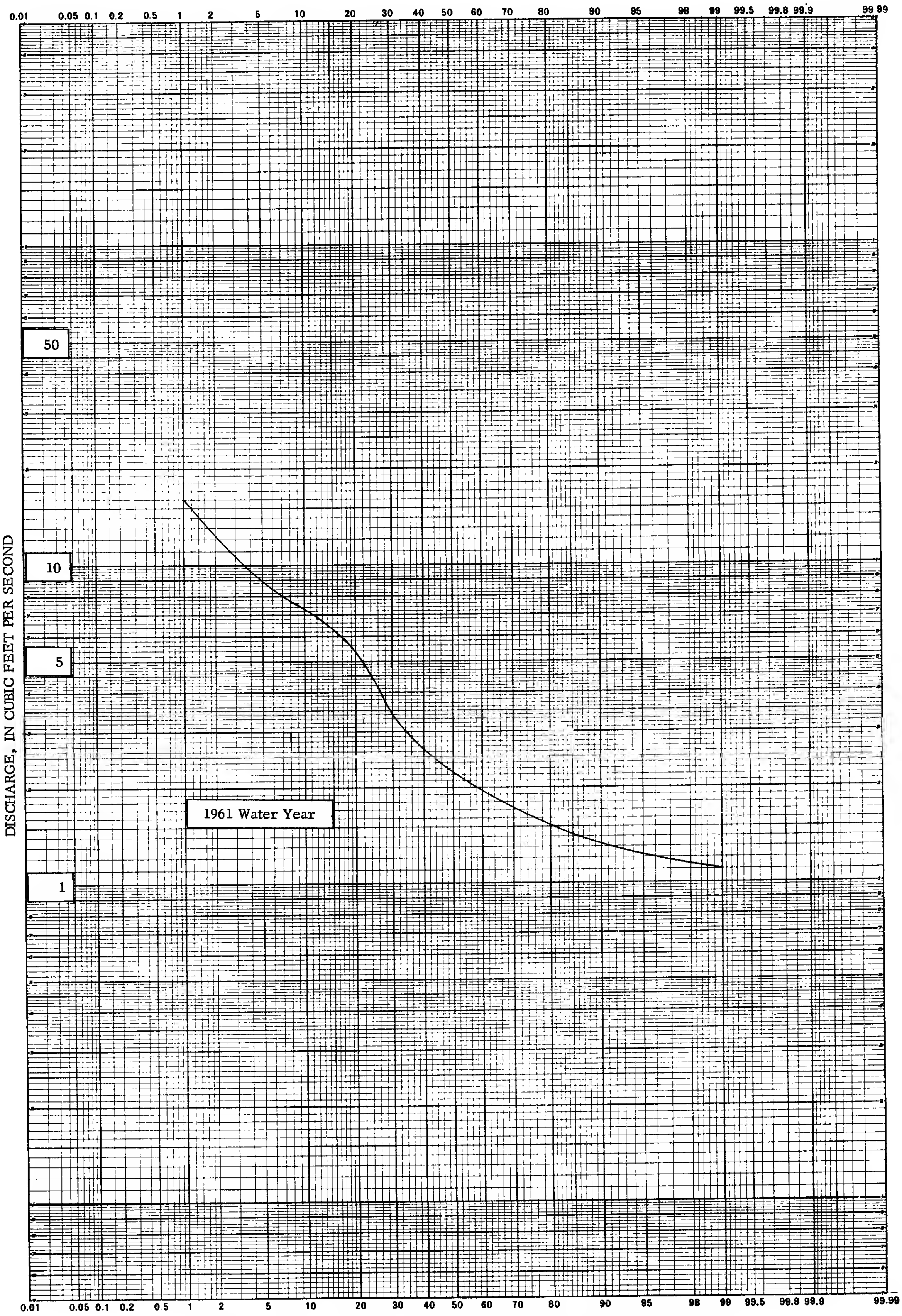

Figure 24.--Duration curve of daily flow, Saddle River near Spring Valley, N. Y.

Table 26. - Chemical analyses of streams in Rockland County

(parts per million)

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Date of collection	Discharge (cfs)	Water temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$		Specific conductance (micromhos at 25°C)	pH	Color
																Ca, Mg	Non-carbonate			
Saddle River near Spring Valley																				
Aug. 31, 1959		71								111						120		280	7.7	
Dec. 3		45	9.8	0.08	0.13	30	7.7	5.2	0.9	95	27	10	0.0	3.8	142	107	29	250	7.5	3
Feb. 11, 1960		48								31						56		148	6.4	
July 12	1.6	72								108						122		273	7.5	
Aug. 31, 1961	1.0	72								101						115		250	7.4	
Pine Brook near Spring Valley																				
Aug. 31, 1959	1.5									90						90		215	7.4	
Dec. 3	1.6	41	7.8	.21	.11	27	5.5	7.5	1.8	69	33	12	.1	4.4	136	90	34	233	7.9	7
Feb. 11, 1960	28	42								45						74		202	6.5	
July 12	.6	71								96						102		238	7.2	
Aug. 31, 1961	.9	76								90						98		238	8.2	
Doodletown Brook at Rt. 9W, Doodletown																				
Sept. 1, 1959		70								32						48		118	7.3	
Dec. 3		41	9.9	.05	.04	8.3	2.4	1.5	.6	10	22	3.3	.2	.2	55	31	23	81	6.5	4
July 13, 1960										54						62		144	7.7	
Aug. 31, 1961		67								24						38		93	6.9	

During the period of record the maximum discharge was 84 cfs (table 27). Minimum flows were regulated considerably and, for parts of five days in 1960, no flow passed the gage. The average daily flow during 1960-61 was 3.87 cfs, equivalent to about 23 inches of runoff.

Because of the extensive amount of artificial pondage on this stream, no effort has been made to correlate the flow record with long-term records at nearby gages. For the same reason, the duration curves should not be used to predict the distribution of flow in future years (fig. 25).

Study of the duration curves points out the mitigating effect of a large amount of pondage which causes the daily flows to fall within relatively narrow limits. A flow equal to or in excess of 1 cfs occurred about 86 percent of the time and equal to or in excess of 10 cfs only about 7 percent of the time.

The chemical quality was similar to that of Saddle River. Both streams drain the same rock types previously described. The dissolved-solids content ranged from about 120 to 142 ppm and the range of hardness was 74 to 102 ppm. Iron and manganese concentrations were higher than those for Saddle River and could be a problem. The combined concentrations were 0.32 ppm. This would be sufficient to cause staining and deposition (table 26).

Table 27. - Summary of Streamflow, Pine Brook near Spring Valley, 1959-61.

Location.--Lat 41°04'42", long 74°04'04", on right bank just downstream from culvert on Pine Brook Road, 200 ft downstream from old dam, 0.45 mile upstream from New York-New Jersey State line, and 2 1/2 miles south of Spring Valley.

Drainage area.--2.28 sq mi.

Records available.--August 1959 to December 1961.

Gage.--Water-stage recorder. Altitude of gage is 335 ft (from topographic map). Prior to July 15, 1960, staff gage at same site and datum.

Extremes.--1958-59: Maximum observed discharge during period August to September, 21 cfs Aug. 9 (gage height, 1.65 ft); minimum observed, 0.3 cfs Sept. 25-30.

1959-60: Maximum discharge during water year, 84 cfs Aug. 19 (gage height, 2.55 ft); minimum, no flow part of each day May 17, June 24, July 8,26,27.

1960-61: Maximum discharge during water year, 69 cfs Feb. 26 (gage height, 2.39 ft); minimum, 0.1 cfs June 6.

Remarks.--Records good. Regulation by small reservoirs above station.

Monthly and yearly mean discharge, in cubic feet per second

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The Year
1959	-	-	-	-	-	-	-	-	-	-	1.26	0.89	-
1960	2.59	2.84	4.37	5.17	7.61	3.95	6.01	2.73	1.05	2.24	3.49	4.41	3.85
1961	1.96	2.08	1.59	2.33	6.85	10.3	9.59	5.10	2.19	2.19	1.33	1.22	3.87

Monthly and yearly runoff, in inches

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The Year
1959	-	-	-	-	-	-	-	-	-	-	0.64	0.44	-
1960	1.31	1.39	2.21	2.62	3.60	1.99	2.94	1.38	0.51	1.13	1.76	2.16	23.00
1961	0.99	1.02	0.80	1.18	3.13	5.19	4.69	2.58	1.07	1.11	0.67	0.60	23.03

Peak discharge (base, 30 cfs)

Date	Time	Gage Height (ft)	Discharge (cfs)	Date	Time	Gage Height (ft)	Discharge (cfs)
12-29-59	Unknown	1.93	36	9-12-60	2:00 pm	2.44	74
1-3-60	Unknown	2.11	47	2-26-61	1:00 am	2.39	69
2-26-60	Unknown	1.86	32	3-14-61	2:00 pm	1.88	33
7-30-60	3:45 pm	2.21	54	4-16-61	5:30 pm	2.20	54
8-19-60	12:30 pm	2.55	84	4-18-61	6:00 pm	1.83	30

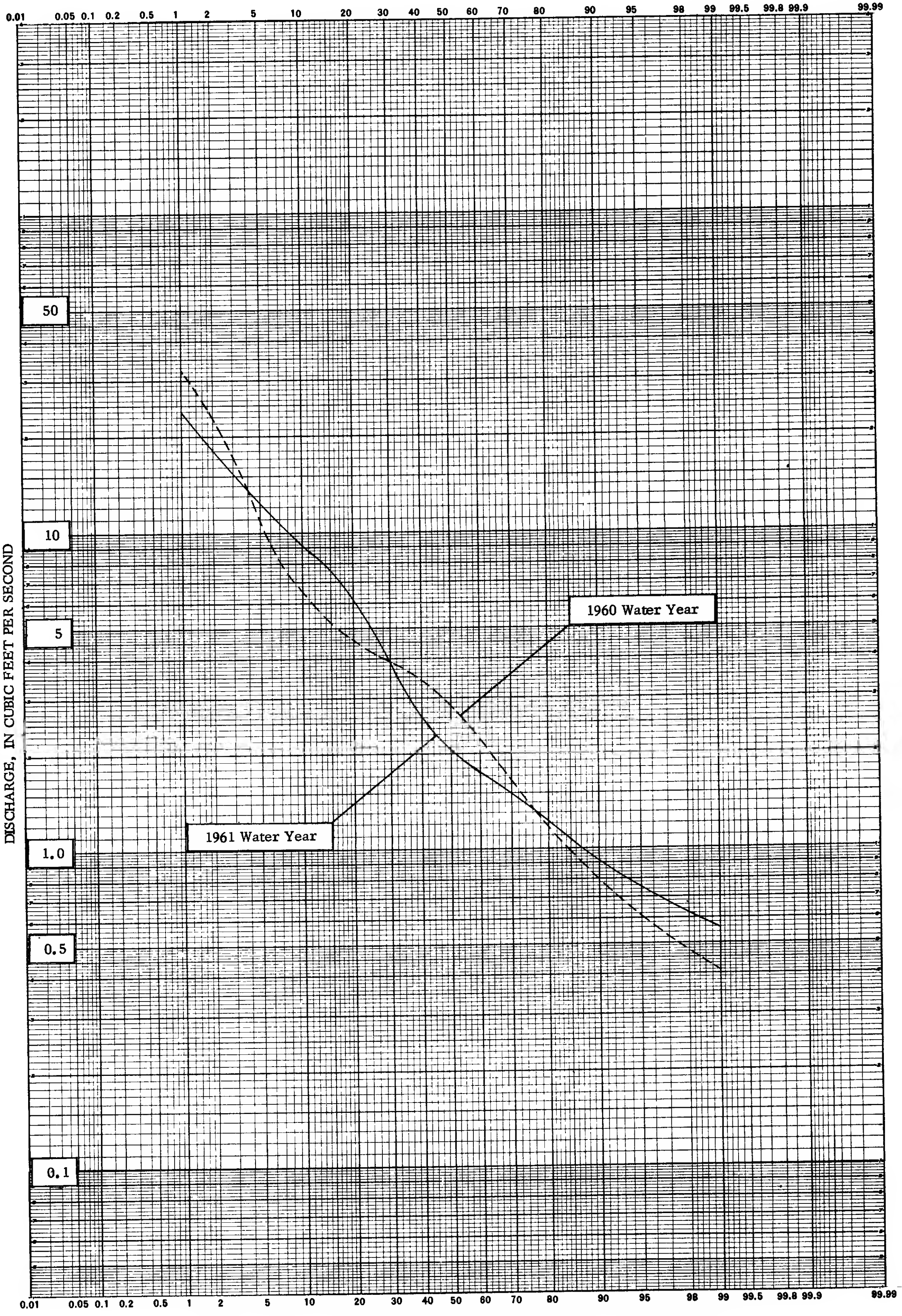


Figure 25.--Duration curves of daily flow, Pine Brook near Spring Valley, N. Y.

MAHWAH RIVER BASIN

The principal drainage in the west-central part of Rockland County is the Mahwah River basin. From its source to the New Jersey State line, it drains 25 square miles of highly variable terrain. The main stem has its source southwest of Letchworth Village, N. Y., at an elevation of 515 feet. The course of the river all the way to the county line is generally southwesterly, parallel to the Ramapo Mountains. During its downward course it receives drainage from the Mountains, some of the tributaries extending to elevations of over 1,000 feet, and from the relatively flat land to the east most of which lies below the 600-ft contour. The area immediately adjacent to the river on both sides is largely swamp land. On some of the tributaries from the east, a number of private ponds have been constructed for recreational purposes.

Mahwah River near Suffern

A streamflow recording gaging station was established on Mahwah River on August 5, 1958 at U. S. Highway 202, about 4 1/2 miles upstream from the river's mouth, in cooperation with the New York State Department of Public Works. This was prior to the beginning of the intensive Rockland County surface-water program. During the period of record the flow past this site varied from a minimum of 0.6 cfs to a maximum of 462 cfs (table 28). During the three-year period the flow averaged 24.5 cfs. Peak discharges in excess of 250 cfs occurred on five occasions.

On figure 26 a comparison is made of curves based on yearly periods of record with a curve representing average conditions over a 26-year period. This curve was developed by correlation with records for Ringwood Creek near Wanaque, N. J., where the stream has been gaged since 1934. Figure 27 shows the comparison of the Ringwood Creek records for 1959, 1960, 1961 with that for a 26-year period.

The shape of the upper and lower ends of the duration curve in figure 26 describes the hydrologic characteristics of Mahwah River. The long-term duration curve indicates that a flow equal to or in excess of 3 cfs can be expected 85 percent of the time and one equal to or in excess of 50 cfs, 12 percent of the time. The relatively flat slopes through the entire length of the curve suggest a moderate flood potential and a better than average low-water yield.

The chemical quality of Mahwah River near Suffern is similar to that of other streams in the southern part of Rockland County. The dissolved-solids content is moderate. In one sample, the concentration of dissolved solids was 80 ppm and the hardness 54 ppm (table 29). On the day of sample collection, the mean daily discharge was 25 cfs. When the mean daily discharge rose to 114 cfs, instead of the expected decrease due to dilution, there was an increase in the dissolved solids to about 93 ppm and in hardness to 73 ppm. A possible explanation is that the increased runoff flushed the swamp areas adjacent to the stream whereby swamp water containing higher concentrations of calcium and magnesium was fed into the main stem. The hardness of water samples collected during low-flow periods was high due to the large proportion of ground-water inflow.

Table 28. - Summary of Streamflow, Mahwah River near Suffern, 1958-61

Location.--Lat 41°08'27", long 74°07'01", on right bank at bridge on U. S. Highway 202, 2 1/2 miles northeast of Suffern.

Drainage area.--12.3 sq mi.

Records available.--August 1958 to December 1961.

Gage.--Water-stage recorder. Altitude of gage is 325 ft (from topographic map).

Extremes.--1958: Maximum discharge during period August to September, 64 cfs Sept. 27 (gage height, 2.81 ft); minimum, 0.6 cfs Sept. 1; minimum daily, 1.3 cfs Sept. 14.

1958-59: Maximum discharge during water year, 291 cfs Mar. 6 (gage height, 4.82 ft); minimum, 1.4 cfs Sept. 27,28.

1959-60: Maximum discharge during water year, 462 cfs Aug. 19 (gage height, 5.76 ft); minimum, 2.0 cfs Oct. 1.

1960-61: Maximum discharge during water year, 334 cfs Feb. 26 (gage height, 5.03 ft); minimum, 2.5 cfs Aug. 18-20.

Remarks.--Records good. Occasional regulation from unknown source.

Monthly and yearly mean discharge, in cubic feet per second

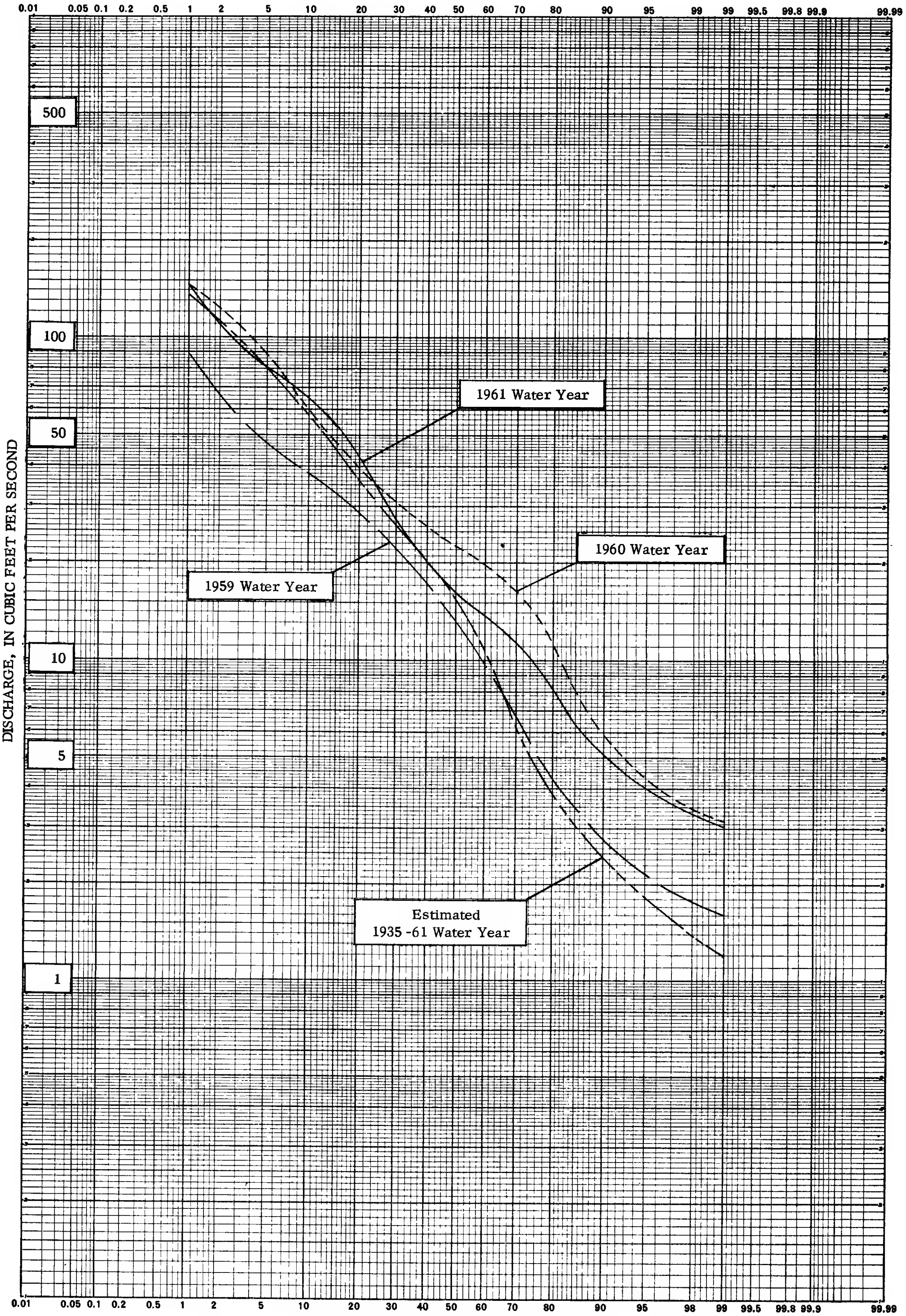
Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The Year
1958	-	-	-	-	-	-	-	-	-	-	4.88	6.91	-
1959	25.7	24.1	22.5	14.7	19.6	37.8	33.3	13.8	8.05	3.56	5.53	2.47	17.6
1960	15.1	24.5	41.5	34.1	46.7	27.0	49.8	23.4	9.96	14.2	31.8	32.0	29.1
1961	15.2	18.2	18.0	18.5	53.9	66.8	62.9	33.0	14.3	10.3	8.03	4.71	26.8

Monthly and yearly runoff, in inches

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The Year
1958	-	-	-	-	-	-	-	-	-	-	0.46	0.63	-
1959	2.41	2.19	2.11	1.38	1.66	3.54	3.02	1.30	0.73	0.33	0.52	0.22	19.41
1960	1.42	2.23	3.89	3.20	4.10	2.53	4.52	2.19	0.90	1.34	2.98	2.91	32.21
1961	1.42	1.65	1.69	1.73	4.56	6.26	5.70	3.09	1.29	0.96	0.75	0.43	29.53

Peak discharge (base, 150 cfs)

Date	Time	Gage Height (ft)	Discharge (cfs)	Date	Time	Gage Height (ft)	Discharge (cfs)
10-27-58	1:30 am	3.66	152	4-5-60	5:00 pm	4.04	198
11-29-58	3:30 am	4.33	233	7-30-60	4:00 pm	4.58	270
3-6-59	4:00 pm	4.82	291	8-19-60	12:30 pm	5.76	462
1-3-60	2:30 pm	4.19	216	9-12-60	7:45 pm	4.88	312
2-11-60	1:00 pm	3.82	171	2-26-61	3:30 am	5.03	334
4-1-60	2:30 am	3.74	162	4-16-61	7:30 pm	4.38	243
				4-18-61	8:00 pm	3.68	155



PERCENT OF TIME INDICATED DISCHARGE WAS EQUALED OR EXCEEDED

Figure 26.--Duration curves of daily flow, Mahwah River near Suffern, N. Y.

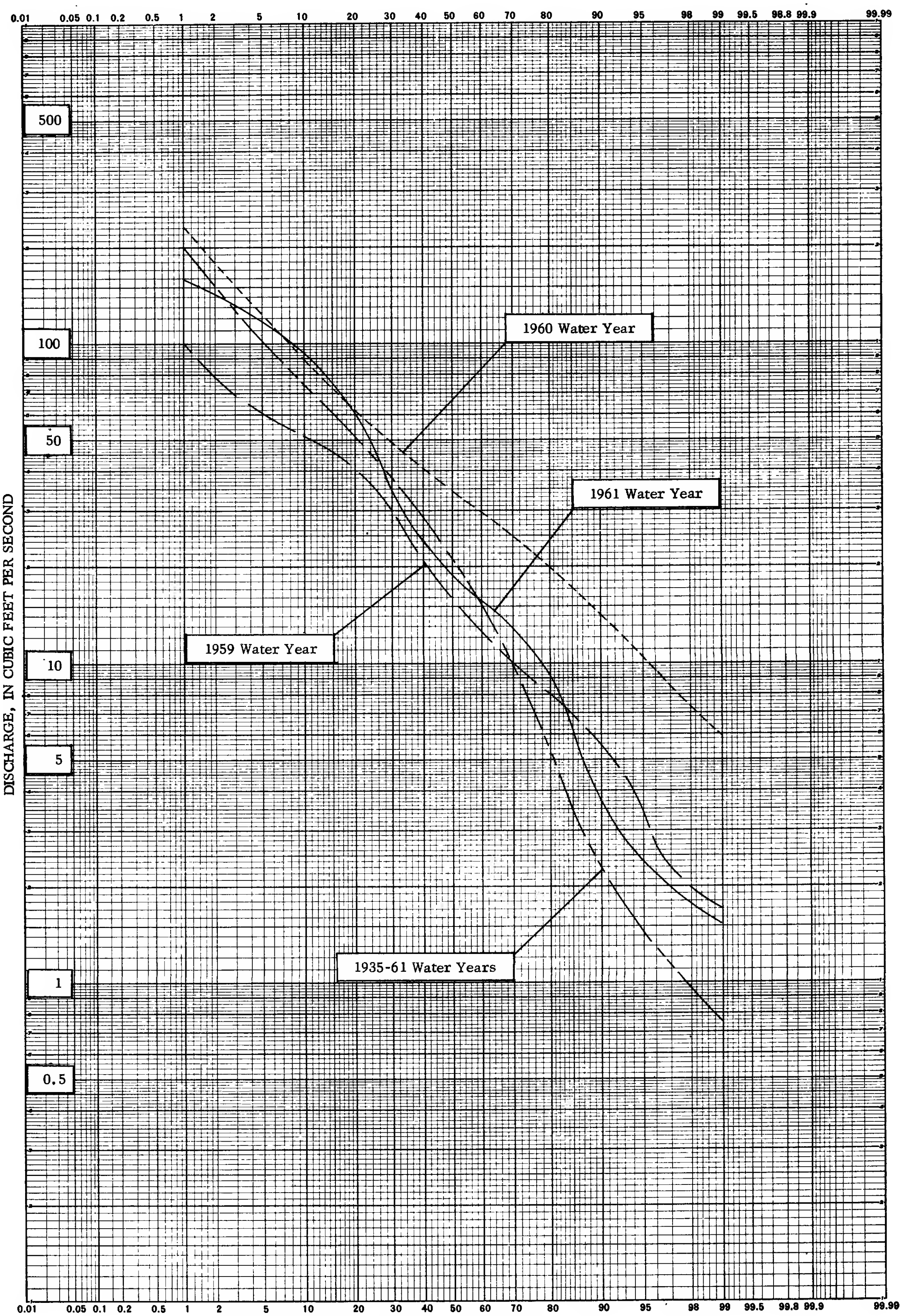


Figure 27.--Duration curves of daily flow, Ringwood Creek near Wanaque, N.J.

Table 29. - Chemical analyses of Mahwah River

(parts per million)

Date of collection	Discharge (cfs)	Water temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$		Specific conductance (micromhos at 25°C)	pH	Color
																Ca, Mg	Noncarbonate			
										Mahwah River near Suffern										
Aug. 31, 1959	3.0	72								100						100		205	7.5	
Dec. 3	25	39	11	0.18	0.14	14	4.6	3.3	0.6	43	22	2.3	0.1	0.9	80	54	19	132	6.9	7
Feb. 11, 1960	114	44								54						73		155	6.3	
July 12	5.0	74								87						86		182	8.0	
Aug. 31, 1961	6.5	76								71						80		167	7.4	
							Mahwah River, above lake, at Suffern													
July 1, 1957	--	72	8.7	.12	.02	28	9.9	4.3	.6	114	17	4.8	.2	.7	135	111	17	233	8.0	9
Mar. 6, 1958	--	38	6.8	.10	.13	13	4.3	2.7	.3	38	17	4.0	.1	.9	71	50	19	110	6.6	5
										Mahwah River at Suffern										
Aug. 31, 1959	12	76								115						110		239	7.5	
Dec. 3	41	38	9.3	.10	.04	18	5.6	3.4	.7	59	21	4.9	.1	1.8	94	68	20	162	7.2	6
Feb. 11, 1960	124	44								53						72		165	6.5	
July 12	9.8	77								111						112		240	7.7	
Oct. 20	45	56		.21						104					131	112		230	7.1	
Aug. 31, 1961	9.8	78								79						89		192	7.1	

The chemical composition of Mahwah River was one of calcium and bicarbonate with lesser amounts of other constituents. Iron and manganese concentrations in one sample were 0.18 and 0.14 ppm, respectively. The combination of the two constituents could present a problem in the use of water from Mahwah River.

Mahwah River at Suffern

Because of the considerable interest in the Suffern area relative to the flood potential and low-flow yield of the Mahwah River, a recording gaging station was established at the upstream side of Lafayette Boulevard (Rt. 59) on Sept. 23, 1959. The drainage area above this site is 20.7 square miles.

The area between this site and the site near Suffern is relatively flat except for a small area of drainage from the Ramapo Mountains extending up to an elevation of over 1,000 feet. A few ponds have been constructed on some of the small tributaries. The New York State Thruway crosses about 1,500 feet upstream from the gage and above this crossing is Lake Antrim which extends under the highway in a man-made channel to a smaller pond downstream. The level of the pond is controlled by a poorly maintained dam 700 feet upstream from the gage. For several years water from the pond was used for washing gravel at a plant on the left bank. No evidence of the regulation by operation of this plant during the period of record was noted on the stage hydrograph. A 12-inch galvanized pipe enters the stream just above the gage and drains the storm runoff from a sizeable paved parking area. Industrial wastes discharged into the river 600 feet upstream discolor the water in the stream at low flows.

Flow in Mahwah River at Suffern during the 1960 water year varied from 4.5 to 664 cfs and in 1961 from 2.6 to 619 cfs (table 30). The average flow for 1960 was 47.2 cfs and for 1961, 42.1 cfs. These average flow rates are equivalent to runoff of 31.1 inches and 27.6 inches, respectively, or 53 percent and 63 percent of the reported precipitation at Suffern.

During the two-year period peak flows in excess of 300 cfs occurred four times. An excellent correlation has existed between the records for the two stations on the Mahwah River. Under normal conditions this high degree of correlation would suggest discontinuing one of the gages. However, since there are problems of pollution abatement and flood control in the Suffern area and also because the Spring Valley Water Works and Supply Company has drilled test wells adjacent to Mahwah River between the two gages, it seems advisable to continue both gaging stations.

Figure 28 shows the duration of daily flows for the 1960 and 1961 water years. These curves show that during the period of record, flow equal to or in excess of 60 cfs occurred 25 percent of the time. In 1960 the flow fell below 10 cfs, 7 percent of the time and in 1961, 15 percent of the time.

Table 30. - Summary of Streamflow, Mahwah River at Suffern, 1959-61

Location.--Lat 41°06'54", long 74°08'46", on right bank at bridge on State Highway 59 (Lafayette Blvd.), at Suffern, and 1 mile upstream from mouth.
Drainage area.--20.7 sq mi.
Records available.--August 1959 to December 1961.
Gage.--Water-stage recorder. Altitude of gage is 275 ft (from topographic map). Prior to September 23, 1959, wire-weight gage at same site and datum.
Extremes.--1958-59: Maximum observed discharge during August and September, 50 cfs Aug. 9,10 (gage height, 3.55 ft); minimum recorded 3.2 cfs Sept. 27,28.
1959-60: Maximum discharge during water year, 664 cfs Aug. 19 (gage height, 5.39 ft); minimum, 4.5 cfs July 27.
1960-61: Maximum discharge during water year, 619 cfs Feb. 26 (gage height, 5.32 ft); minimum, 2.6 cfs Aug. 19,20.
Remarks.--Records good.

Monthly and yearly mean discharge, in cubic feet per second

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The Year
1959	-	-	-	-	-	-	-	-	-	-	12.1	6.00	-
1960	25.33	38.2	64.4	56.9	74.5	45.4	78.0	40.9	18.9	23.3	48.8	54.0	47.2
1961	26.7	28.2	27.6	29.8	76.3	107	96.5	55.6	23.5	17.1	12.3	7.47	42.1

Monthly and yearly runoff, in inches

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The Year
1959	-	-	-	-	-	-	-	-	-	-	0.67	0.32	-
1960	1.41	2.06	3.59	3.17	3.88	2.53	4.20	2.28	1.02	1.30	2.72	2.91	31.07
1961	1.49	1.52	1.54	1.66	3.84	5.93	5.20	3.10	1.26	0.95	0.69	0.40	27.58

Peak discharge (base, 200 cfs)

Date	Time	Gage Height (ft)	Discharge (cfs)	Date	Time	Gage Height (ft)	Discharge (cfs)
1-3-60	9:30 pm	4.46	235	9-13-60	1:00 am	4.93	411
4-5-60	5-8 pm	4.45	232	2-26-61	9:00 am	5.32	619
7-30-60	12:00 pm	4.63	291	4-17-61	1:00 am	4.73	328
8-19-60	8:00 pm	5.39	664				

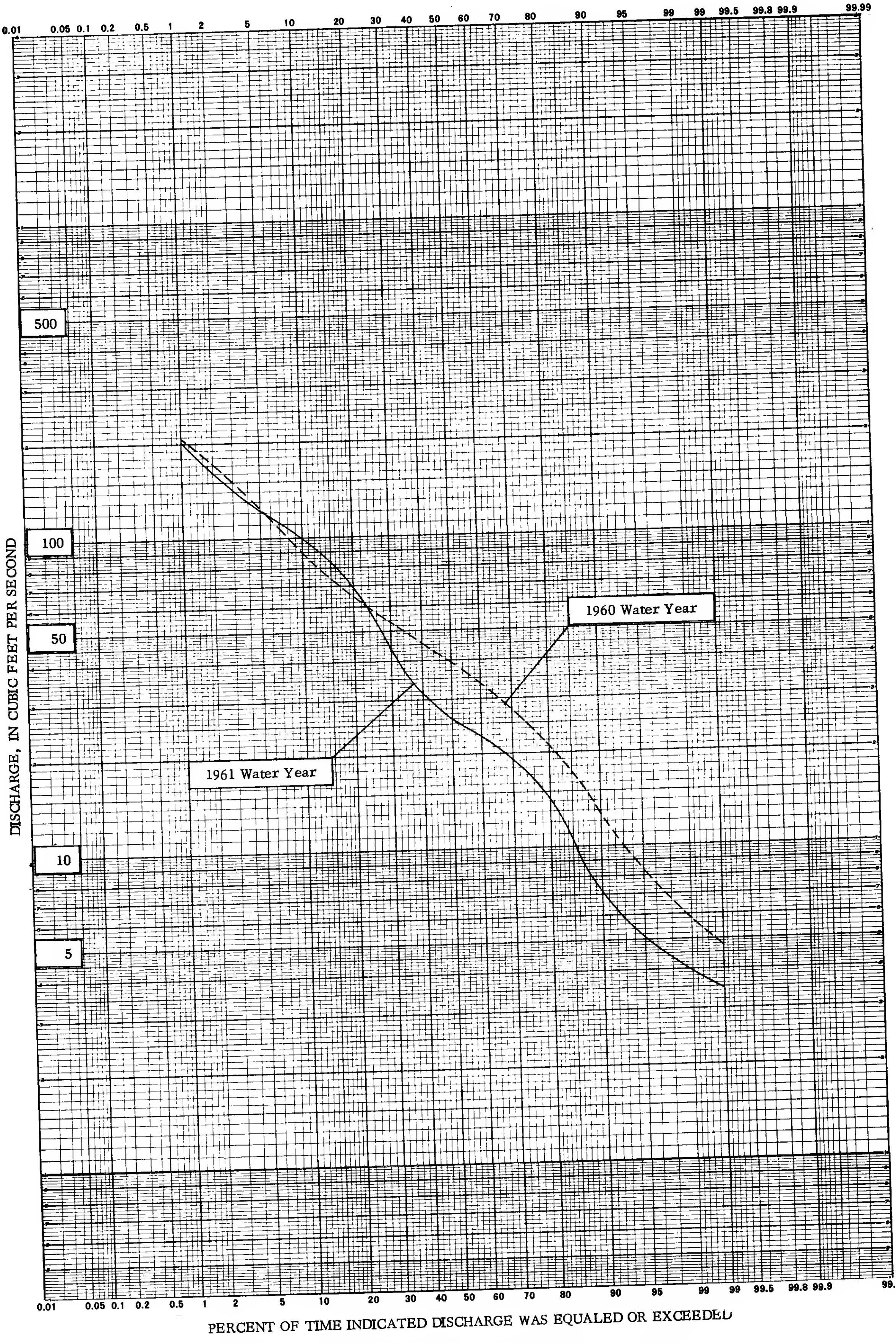


Figure 28.--Duration curves of daily flow, Mahwah River at Suffern, N. Y.

At Suffern, water from Mahwah River contained more dissolved solids and was harder than at the upstream site. The dissolved-solids content (based on specific conductance) ranged from 96 to 144 ppm and the hardness ranged from 68 to 112 ppm (table 29). Here, too, there was a wide variation in the dissolved-solids content for about the same rate of discharge. When stream discharge was 41 cfs (mean daily) the dissolved-solids content was 94 ppm and the hardness was 68 ppm. At another time, when the mean daily discharge was 45 cfs, the dissolved-solids content rose to 131 ppm and the hardness was 112 ppm. In contrast, when discharge was 9.8 cfs the hardness was 112 ppm. At another time for the same discharge, hardness dropped to 89 ppm. Because of the effect of water drained from the swamp areas, there appears to be very little relationship between stream discharge and dissolved-solids content.

The chemical composition was similar to that of other streams in Rockland County -- calcium and bicarbonate. Other constituents were present in lesser amounts. Iron and manganese concentrations in one water sample were 0.10 and 0.04 ppm, respectively. What the concentrations would be during the low flows is not known.

RAMAPO RIVER BASIN

Ramapo River rises in Orange County in Placid Pond near Walton Park at an elevation of 690 feet with some minor tributaries starting as high as 830 feet. The river flows northeast for 1 3/4 miles to the Village of Monroe, through a series of small ponds and swamp areas. From Monroe it flows southeast for 3 1/2 miles to Harriman. There it takes a southwesterly course for 2 1/3 miles to Arden where it is joined by Arden Brook, a tributary from the east rising in Cranberry and Forest Lakes. From Arden the Ramapo flows about six miles southwest and five miles south until it crosses into Rockland County between the Villages of Tuxedo Park and Sloatsburg.

Before the River reaches the Rockland County line it has provided water supply for several villages and has served for waste disposal either sanitary or industrial at several different points. Most of the wastes have received some sort of treatment before being discharged into the river.

Ramapo River at Sloatsburg

Examination of table 31 shows a minimum flow of 4.7 cfs in Ramapo River at a site 1/2 mile south of the Rockland County line. Peak flows in excess of 1,000 cfs occurred five times between September 1959 and December 1961. A peak discharge of about 6,000 cfs is known to have occurred in October 1955.

Figure 29 shows the flow duration curves for the Ramapo River at Sloatsburg site for the 1960 and 1961 water years. Also included as a dashed line is the duration curve for a 26-year period based on correlation techniques. Notice the spread between the three curves at the lower extremities and, in particular, the fact that the long-term curve is lower below the 70 percent duration point than either of the other curves. Over a long term, a flow equal to or in excess of 8 cfs could be expected 90 percent of the time and 300 cfs or more, 8 percent of the time.

There is a distinct difference in the chemical quality of the headwaters of Ramapo River in Orange County and that of the river and its tributaries in Rockland County. In the upper reaches, the Ramapo River drains a limestone area and the chemical quality is characteristic of drainage from this type of rock. The chemical composition is principally one of calcium and bicarbonate, with lesser amounts of magnesium and sulfate. Three analyses were made of water samples from the Ramapo River collected at Harriman. The last sample was collected in 1960 during a low-flow period. It contained 198 ppm of dissolved solids and was moderately hard - 97 ppm (table 32). But, one sample collected in 1957 (also during a low-flow period) had a dissolved-solids content of 189 ppm and was hard; hardness was 135 ppm. The reason for the difference is indicated by the pH and bicarbonate concentration. The water sample collected in 1960 was slightly acid - pH 6.0 and contained less bicarbonate. Conversely, the sample collected in 1957 was alkaline - pH 7.3 and contained 138 ppm of bicarbonate.

Table 31. - Summary of Streamflow, Ramapo River at Sloatsburg, 1959-61

Location.--Lat 41°10'08", long 74°11'27", on left bank 300 ft upstream from Washington Ave. bridge, 600 ft downstream from unnamed tributary, at Sloatsburg, and 0.6 mile upstream from Stony Brook.
Drainage area.--60.9 sq mi.
Records available.--September 1959 to December 1961.
Gage.--Water-stage recorder. Altitude of gage is 365 ft (from topographic map).
Extremes.--1959: Minimum discharge during September, 5.0 cfs Sept. 27.
1959-60: Maximum discharge during water year, 2,270 cfs Aug. 19 (gage height, 9.52 ft); minimum, 5.3 cfs Oct. 1.
1960-61: Maximum discharge during water year, 1,920 cfs Feb. 26 (gage height, 9.15 ft); minimum, 4.7 cfs Aug. 19.
Flood of October 16, 1955 reached a stage of 12.2 ft (from floodmarks).
Remarks.--Records good.

Monthly and yearly mean discharge, in cubic feet per second

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The Year
1960	98.1	148	195	162	211	118	274	79.0	64.4	109	267	226	162
1961	51.9	53.0	59.0	60.9	268	330	298	174	68.1	23.4	13.3	16.1	117

Monthly and yearly runoff, in inches

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The Year
1960	1.86	2.70	3.70	3.06	3.74	2.23	5.02	1.50	1.18	2.05	5.05	4.13	36.22
1961	0.98	0.97	1.12	1.15	4.59	6.24	5.45	3.28	1.25	0.44	0.25	0.30	26.02

Peak discharge (base, 800 cfs)

Date	Time	Gage Height (ft)	Discharge (cfs)	Date	Time	Gage Height (ft)	Discharge (cfs)
1-4-60	4:00 am	7.61	835	7-31-60	Unknown	8.26	1,250
2-12-60	2:00 am	7.55	800	8-19-60	12:00 pm	9.52	2,270
4-1-60	1-3 am	7.66	866	9-13-60	4-5 am	8.81	1,640
4-5-60	7:00 pm	8.32	1,290	2-26-61	11:00 am	9.15	1,920

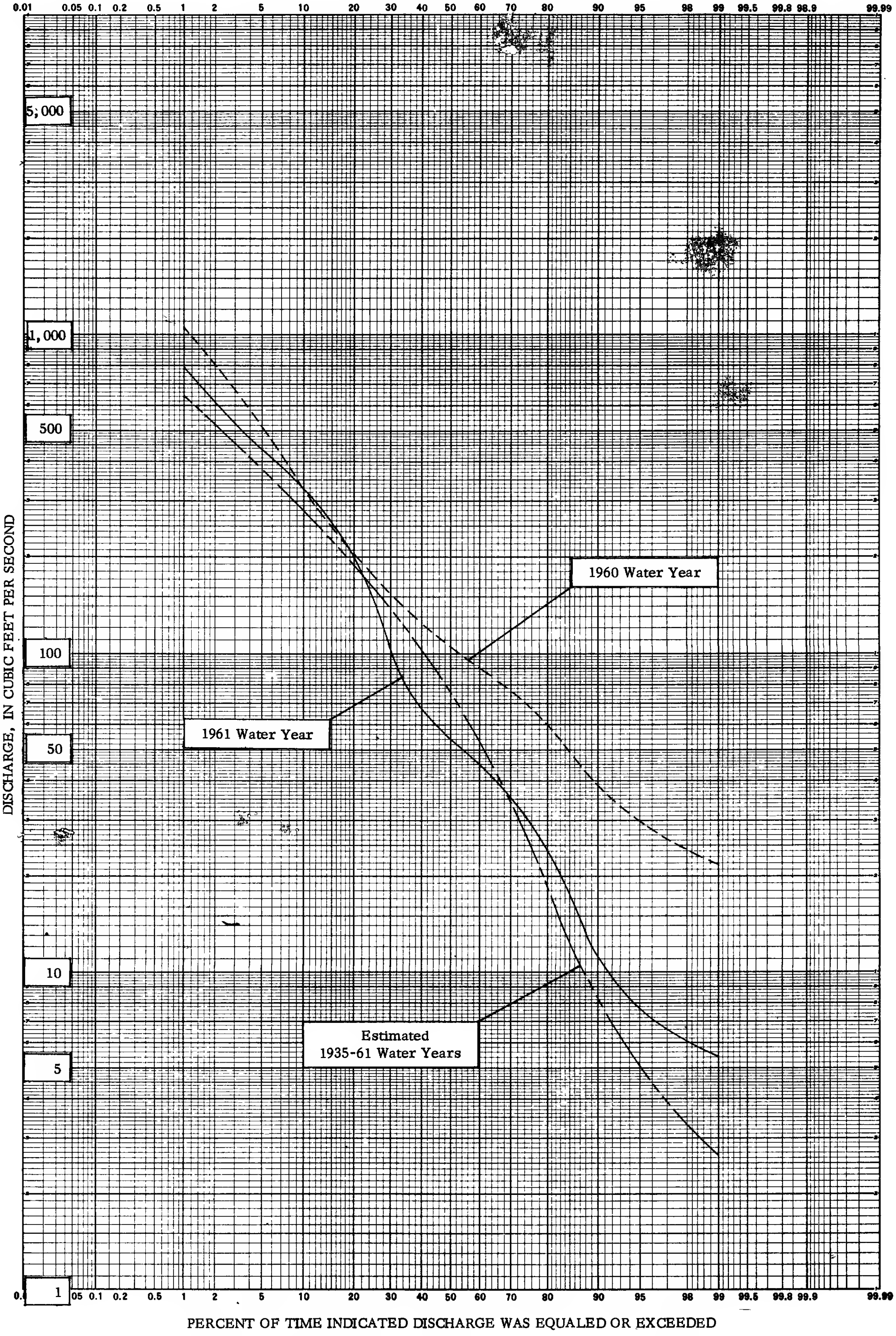


Figure 29.--Duration curves of daily flow, Ramapo River at Sloatsburg, N. Y.

Table 32. - Chemical analyses of streams

in the Ramapo River basin

(parts per million)

38947

Date of collection	Discharge (cfs)	Water temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$		Specific conductance (micromhos at 25°C)	pH	Color
																Ca, Mg	Noncarbonate			
Ramapo River at Harriman																				
July 1, 1957		69	3.6	0.37	0.14	34	12	13	1.8	138	23	16	0.6	3.1	189	135	21	324	7.3	19
April 8, 1958		46	4.1	.19	.03	14	3.9	3.1	1.2	36	20	5.0	.2	3.1	80	51	22	127	6.3	3
Oct. 20, 1960		56		.30						76					198	97		335	6.0	
Ramapo River at Sloatsburg																				
Aug. 31, 1959	--	74								78						94		218	7.5	
Dec. 3	146	39	6.2	.15	.04	14	4.4	2.5	.9	34	16	7.3	.2	1.5	78	53		133	7.2	6
Feb. 11, 1960	456	42								22						42		110	6.2	
July 12	34	79								70						86		202	7.4	
Aug. 31, 1961	14	79								64						78		195	7.3	
Stony Brook at Sloatsburg																				
Aug. 31, 1959	--	72								16						24		61	7.1	
Dec. 3	11	39	7.4	.06	.03	5.0	1.7	1.5	.5	6	12	2.8	.3	.4	38	20	15	55	6.4	2
Feb. 11, 1960	205	42								3						18		52	5.4	
July 12	7.6	79								18						25		71	7.4	
Aug. 31, 1961	6.9	75								15						23		66	6.8	
Ramapo River Tributary at Sloatsburg																				
Aug. 31, 1959		76								36						38		85	7.3	
Dec. 3		39	8.6	.14	.08	5.8	1.6	2.5	.7	12	16	22.2	.0	.6	46	21	11	67	6.0	7
Feb. 11, 1960		42								8						22		61	5.6	
July 12		82								35						38		93	7.4	
Aug. 31, 1961		78								30						38		92	7.0	
Torne Brook at Ramapo																				
Aug. 31, 1959		71								41						46		102	8.0	
Dec. 3		39	10	.04	.04	4.8	.6	2.3	.7	5	14	2.7	.2	.2	41	15	6	57	6.6	3
Feb. 11, 1960		42								3						17		51	5.3	
July 12		67								14						21		61	7.0	
Aug. 31, 1961		71								18						21		67	6.8	

Dilution was effective in reducing the dissolved-solids content and hardness. During a high-flow period in 1958, in one water sample the dissolved-solids content was only 80 ppm and the hardness 51 ppm. In two of the water samples collected at Harriman iron concentrations were sufficient to stain and deposit.

Farther downstream the Ramapo River drains a crystalline rock area and continues to do so as it crosses intc Rockland County. Because of the geology there is a substantial reduction in the dissolved-solids content and hardness. The effect of drainage from the limestone area is reduced by inflow of less mineralized water from crystalline rocks. One water sample collected at Sloatsburg (when mean daily discharge was 146 cfs) had a dissolved-solids content of 78 ppm and a hardness of 53 ppm. In three samples collected during low-flow periods the dissolved-solids content was estimated to be about 120 ppm based on specific conductance measurements, and the hardness was from 78 to 94 ppm (table 32). In contrast, one water sample collected during a mean daily discharge of 456 cfs, contained about 66 ppm of dissolved solids and its hardness was 42 ppm. Although iron and manganese concentrations were low in one water sample, sufficient information is not available, at this time, to determine whether these two constituents would be a problem in the utility of water from Ramapo River.

Several water samples were collected for the determination of sediment load. Although the data are not sufficient to appraise the sediment characteristics of Ramapo River there is some indication that, at times, Ramapo River transports a sizeable sediment load. At an instantaneous discharge of 381 cfs, the estimated sediment load was 106 tons per day.

Stony Brook at Sloatsburg

Early in the study of the Ramapo River Basin, it was noted that an unusual condition appeared to exist during low-flow periods between the Ramapo River at Sloatsburg and a long-term station near Mahwah, New Jersey. For this reason a recording gaging station was installed on Stony Brook at the Waldron Terrace Bridge, about 900 feet upstream from the mouth.

From the summary in table 33, a variation in flow from a minimum of 0.6 cfs to a maximum of 1,060 cfs is shown. During the period of record a flow in excess of 500 cfs occurred on four occasions. The average flow for 1960 was 47.7 cfs, equivalent to 35.6 inches of runoff and for 1961, 41.9 cfs, equal to 31.2 inches of runoff. These figures of runoff are the highest recorded in the entire Rockland County area and represent 61 percent and 71 percent of the precipitation recorded at Suffern. Flow during the period of record equalled or exceeded 60 cfs 20 percent of the time (fig. 30). In 1960 flow was less than 5 cfs, 3 percent of the time and in 1961, 8 percent of the time. The shape of the low end of the 1961 curve is the result of regulation of Sebago Lake.

Table 33. - Summary of Streamflow, Stony Brook at Sloatsburg, 1959-61

Location.--Lat 41°09'44", long 74°11'10", on left bank at downstream side of Waldron Terrace bridge, at Sloatsburg, 900 ft upstream from mouth, and 1 1/2 miles downstream from Spring Brook.

Drainage area.--18.2 sq mi.

Records available.--October 1959 to December 1961. Low-flow partial-record station July 1956 to September 1958.

Gage.--Water-stage recorder. Altitude of gage is 375 ft (from topographic map).

Extremes.--1959-60: Maximum discharge during water year, 1,060 cfs Aug. 19 (gage height, 3.14 ft); minimum, 1.3 cfs July 27, minimum daily 2.1 cfs July 26.

1960-61: Maximum discharge during water year, 861 cfs Feb. 26 (gage height, 2.85 ft); minimum daily, 0.6 cfs Aug. 3,4.

Remarks.--Sebago Lake was dropped eleven feet over the period from Sept. 15, 1959 to Nov. 15, 1959. Other years Sebago Lake was dropped two feet between Sept. 15 and Nov. 15. The gate is closed at other times.

Monthly and yearly mean discharge, in cubic feet per second

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The Year
1959-60	59.6	12.0	26.9	57.4	71.0	39.3	79.5	27.0	14.5	33.4	72.5	80.0	47.7
1960-61	17.9	26.2	26.4	15.5	92.9	113	106	50.5	21.5	13.4	5.79	18.2	41.9

Monthly and yearly runoff, in inches

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The Year
1959-60	3.78	0.74	1.71	3.63	4.21	2.49	4.87	1.71	0.89	2.12	4.59	4.90	35.64
1960-61	1.13	1.60	1.67	0.98	5.31	7.19	6.49	3.20	1.32	0.85	0.37	1.11	31.22

Peak discharge (base, 250 cfs)

Date	Time	Gage Height (ft)	Discharge (cfs)	Date	Time	Gage Height (ft)	Discharge (cfs)
1-3-60	7-8 pm	1.79	301	8-19-60	10:15 pm	3.14	1,060
2-11-60	6:00 pm	1.72	273	9-12-60	6:00 pm	2.62	719
3-31-60	10:00 pm	2.12	440	2-26-61	3:30 am	2.85	861
4-5-60	3:30 pm	1.99	398	4-16-61	5:30 pm	1.87	351
7-30-60	3:00 pm	2.32	541				

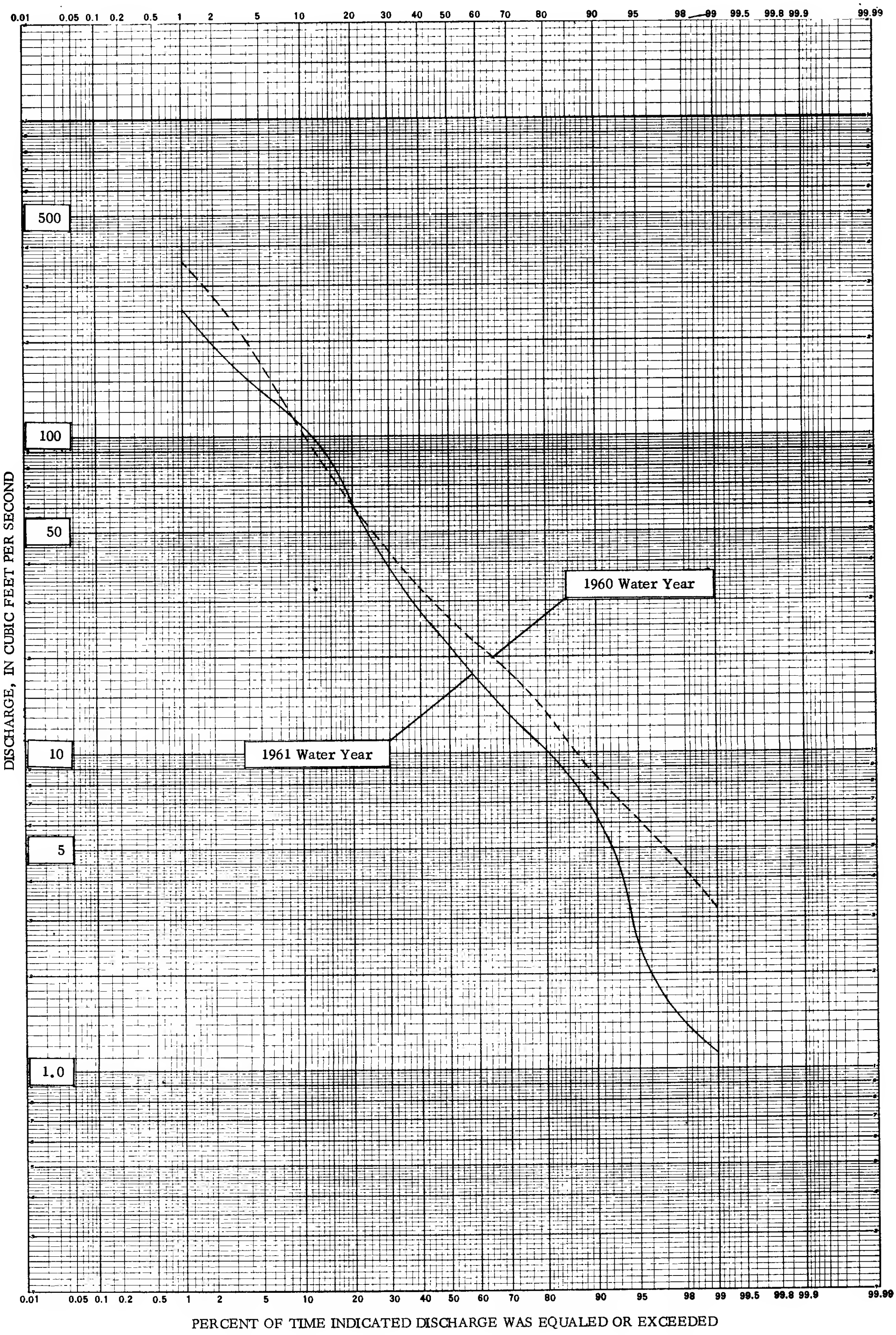


Figure 30.--Duration curves of daily flow, Stony Brook at Sloatsburg, N. Y.

The unusual conditions of flow referred to above have been identified as due to release of water from Sebago Lake which reaches Ramapo River by way of Stony Brook, often at a time when extremely low flows are occurring in the main river. This extra water has caused a man-made change in the low-flow frequency pattern at the downstream station near Mahwah, resulting in an unreliable estimate of normal low flows in the stream. This could be a serious problem if design of waste treatment facilities were based on the record for the gaging station on Ramapo River near Mahwah.

Correspondence with the Palisades Interstate Park Commission authorities confirms the assumption that the occurrence of additional release water with low flows in the main river above Sloatsburg is coincidental since no commitment exists to release water from Sebago Lake for maintenance of higher low-water flows in the main river. Release from Sebago Lake is a rather routine procedure followed by the Commission to protect the lake shores from damage during the late fall, winter, and spring or to permit more effective maintenance and repair of the facilities adjacent to the lake.

Stony Brook drains a crystalline rock area. Very little solution of mineral matter takes place and this is reflected in the chemical quality. The dissolved-solids content in one water sample was 38 ppm (table 32). Based on specific-conductance measurements, the estimated range in several samples was about 30 to 40 ppm, irrespective of streamflow conditions. Iron and manganese concentrations in one sample collected during moderate flow were less than 0.1 ppm. What the concentrations would be during low flow is not known. Usually an increase can be expected.

However, water from Stony Brook could be corrosive. The pH of one water sample was 5.4, an indication of moderate acidity. The pH of other samples was near or above the neutral point of 7.0.

Ramapo River Tributary at Sloatsburg

At a point a mile downstream from the mouth of Stony Brook, the flow of Ramapo River Tributary enters Ramapo River. This flow represents the spillage from Cranberry and Potake Ponds together with the flow from Long Swamp located northwest of Sloatsburg.

At a site a short distance upstream from Route 17 and just below the confluence of the two branches 14 discharge measurements were made, including seven made under baseflow conditions (table 34). On each occasion measurements were made of the flow in Cranberry Pond Outlet so that the proportionate flow of each stream could be evaluated (table 50). Cranberry and Potake Ponds are used as sources of public water supply for the Village of Sloatsburg where about 2,600 persons are reported to use an average of 0.4 mgd, equivalent to a flow of about 0.6 cfs.

Most of the flow in Ramapo River Tributary during low-flow periods is from the Long Swamp area. Since there is diversion from the Tributary it is not possible at this time to correlate the flow with that of nearby streams. The lower reaches of Ramapo River Tributary are polluted by the overflow from several septic tanks as is apparent by a very unpleasant odor in the area during periods of low flow in the stream.

The chemical quality of the tributary was similar to that of Stony Brook-low dissolved solids and hardness. The estimated range of dissolved solids (based on specific conductance) was 40 to 55 ppm. The range of hardness of water from the tributary was 21 to 38 ppm (table 32). Generally, on the basis of mineral content, water from this tributary is satisfactory for most uses. One water sample was acid; the pH was 5.6. Because of the acid condition, the water could be corrosive. Other water samples were alkaline. Whether this acid condition is a seasonal characteristic or a chance occurrence is not known.

Table 34. - Summary of Discharge Measurements, Ramapo River Tributary

at Sloatsburg

Date	Discharge (cfs)	Date	Discharge (cfs)
July 21, 1959	0.86	Apr. 4, 1960	52.6
Aug. 6, 1959	2.36	Sept. 28, 1960	8.79
Sept. 22, 1959	.51	Sept. 5, 1961	.49
Oct. 26, 1959	19.3	Sept. 21, 1961	2.03
Mar. 21, 1960	7.93	Oct. 6, 1961	.60
Mar. 31, 1960	42.3	Oct. 30, 1961	6.27
Apr. 1, 1960	41.2	Mar. 19, 1962	24.3

Torne Brook at Ramapo

Staff and crest-stage gages were installed on Torne Brook about 1/4 mile upstream from its mouth. This site was selected for inclusion in the study since the stream drains a basin which at the present time is entirely undeveloped. The drainage area of 2.62 square miles ranges in elevation from 300 feet to over 1200 feet. Most of it lies in the Ramapo Mountains but none falls within the boundary of the Palisades Interstate Park. Therefore it may appeal to real estate developers in the future.

Fourteen discharge measurements have been made, seven of them under baseflow conditions (table 35). The results of these measurements have been correlated with the discharge of Mahwah River at corresponding times. Sufficient data are not yet available to enable development of a duration curve by correlation techniques.

As do the other streams in the Ramapo River basin previously discussed, Torne Brook drains a crystalline rock area. Such rock is only slightly soluble. Consequently, the chemical quality consists of a low dissolved-solids content and the water is soft. The estimated range of dissolved solids in five samples was about 30 to 60 ppm, and the hardness 15 to 46 ppm (table 32).

Water from Torne Brook on February 11, 1961 had a low pH - 5.3. This is considered acid. In contrast, one water sample was alkaline - pH 8.0. With the exception of the acid condition, water from Torne Brook appears satisfactory for most uses.

Table 35. - Summary of Discharge Measurements, Torne Brook at Ramapo

Date	Discharge (cfs)	Date	Discharge (cfs)
July 21, 1959	0.90	May 25, 1960	8.13
Aug. 6, 1959	1.20	Aug. 19, 1960	310
Sept. 23, 1959	.16	Sept. 28, 1960	3.50
Oct. 26, 1959	9.50	Sept. 21, 1961	6.28
Mar. 21, 1960	4.15	Oct. 6, 1961	.46
Mar. 31, 1960	41.8	Oct. 30, 1961	.33
Apr. 1, 1960	24.1	Mar. 19, 1962	11.4

Ramapo River near Mahwah, N. J.

Although the gaging station on Ramapo River near Mahwah, N. J., (drainage area 118 square miles), is not included in the present cooperative stream-gaging program in Rockland County and physically lies outside the boundaries of the County, it is discussed here because it has been in continuous operation since September 1922. It integrates the flow of the Ramapo River as it leaves New York State augmented by the flow of Mahwah River together with a small amount of ungaged area.

The average flow at this site on Ramapo River for the period 1922-61 was about 230 cfs with a minimum of 7 cfs and a maximum of 12,400 cfs.

Ordinarily a record of flow such as has been collected at this site over a long period of time would serve as an excellent basis for evaluating the low-flow characteristics of the Ramapo River. However, the uncertain flow pattern of Stony Brook, a major tributary, helps to point out the danger of using a station record for statistical analysis without thorough knowledge of the nature of the base data.

Based on the pattern of flow in Ramapo River near Mahwah, N. J., the minimum average consecutive 7-day discharge to be expected once in a 10-year period is 13 cfs or 0.11 cfs per square mile. Using this unit rate of flow, a figure of 9.5 cfs has been determined for Ramapo River at the New York-New Jersey State line. If, however, the same computations are made for Ramapo River at Sloatsburg and prorated to the site at the state line, a minimum average consecutive 7-day discharge with a recurrence interval of 10 years is less than 5 cfs or about half that computed from the downstream site. This difference in values is due entirely to the unpredictable flow pattern of Stony Brook resulting from regulation of the flow in the Brook at the convenience of the Palisades Interstate Park Commission.

Doodletown Brook at Doodletown

A staff gage was installed on Doodletown Brook at U. S. Highway 9 in 1959. The Brook at this site drains 2.91 square miles of relatively steep slopes up to elevations in excess of 1,000 feet. The influence of Hudson River tidewater extends to a point a few feet upstream from the gage so that a stage-discharge relation could not be established during periods of high tide.

Because of the potential this stream offered for public water supply (Iona Island at the mouth already uses a small amount of water collected in an infiltration gallery in the headwaters) and because the stream was unaffected by ponds, swamps or man-made structures, base-flow discharge measurements were made to determine if the flow pattern could be correlated with a continuous record of flow at some nearby site. In addition, temperature of the water and of the air at the time of measurements, was recorded. Results of these measurements appear in table 36.

Water samples collected from Doodletown Brook had an estimated dissolved-solids range of from 50 to 85 ppm and the hardness ranged from 31 to 62 ppm (table 26). The low dissolved-solids content consists principally of calcium and bicarbonate. Iron and manganese concentrations were insignificant in one sample, and it is assumed that no problem would arise in the use of the water from this stream.

Table 36. - Summary of Discharge Measurements, Doodletown Brook at Doodletown

Date	Discharge (cfs)	Date	Discharge (cfs)
July 20, 1959	0.01	Mar. 31, 1960	52.5
Aug. 6, 1959	.30	June 29, 1960	.50
Oct. 6, 1959	.18	Sept. 27, 1960	3.78
Mar. 23, 1960	3.61	Sept. 27, 1961	.29
Mar. 29, 1960	8.60	Mar. 26, 1962	10.3
Mar. 30, 1960	13.2		

Streamflow Variability

As noted earlier in this report, precipitation in Rockland County is highly variable both with respect to time and place. Since streamflow results from precipitation it too is highly variable.

The day-to-day variation in streamflow as it passed the gage on Hackensack River at Brookside Park during water year 1961 has been plotted as figure 31. This is a typical hydrograph for a Rockland County stream for 1961 with the higher flows occurring in the late winter and early spring and the lower flows during the late summer and early fall.

During the 1961 water year the total rainfall was slightly below normal, but the occurrence of above-average rainfall throughout the ordinarily drier summer months helped to maintain streamflow above the low flows usually experienced. Some precipitation was recorded for 112 days (fig. 31).

Duration curves are a useful tool to illustrate geographical variability of streamflow throughout the County, and even within some of the individual river basins. In order for the duration curves for gaging stations with various size drainage areas to lend themselves to this approach, flow data must be reduced to a common unit, such as cubic feet per second per square mile (csm). Such duration curves usually tend to be closely grouped or at least somewhat parallel between about 20 and 70% duration points, but they tend to diverge widely below this. Such divergence is not unusual and it may result from man-made regulation or from the basin characteristics, such as, elevation, geology, vegetable cover, and percent of urbanization.

Geographical variability in streamflow throughout Rockland County as a whole and within some of the individual river basins is shown in figures 32, 33, and 34.

Figure 32 is a plot of the duration curves of daily flow for the 1961 water year for streams discharging into the Hudson River. Between the 20 and 70% points the curves are rather uniformly spread and somewhat parallel. At the 20% point the greatest variation is between Sparkill Creek at Tappan and Lake Tiorati Brook at Cedar Flats. Factors affecting the low-end spread and shapes of the curves include elevation, geology, vegetal cover, percent of urbanization, and man-made regulation.

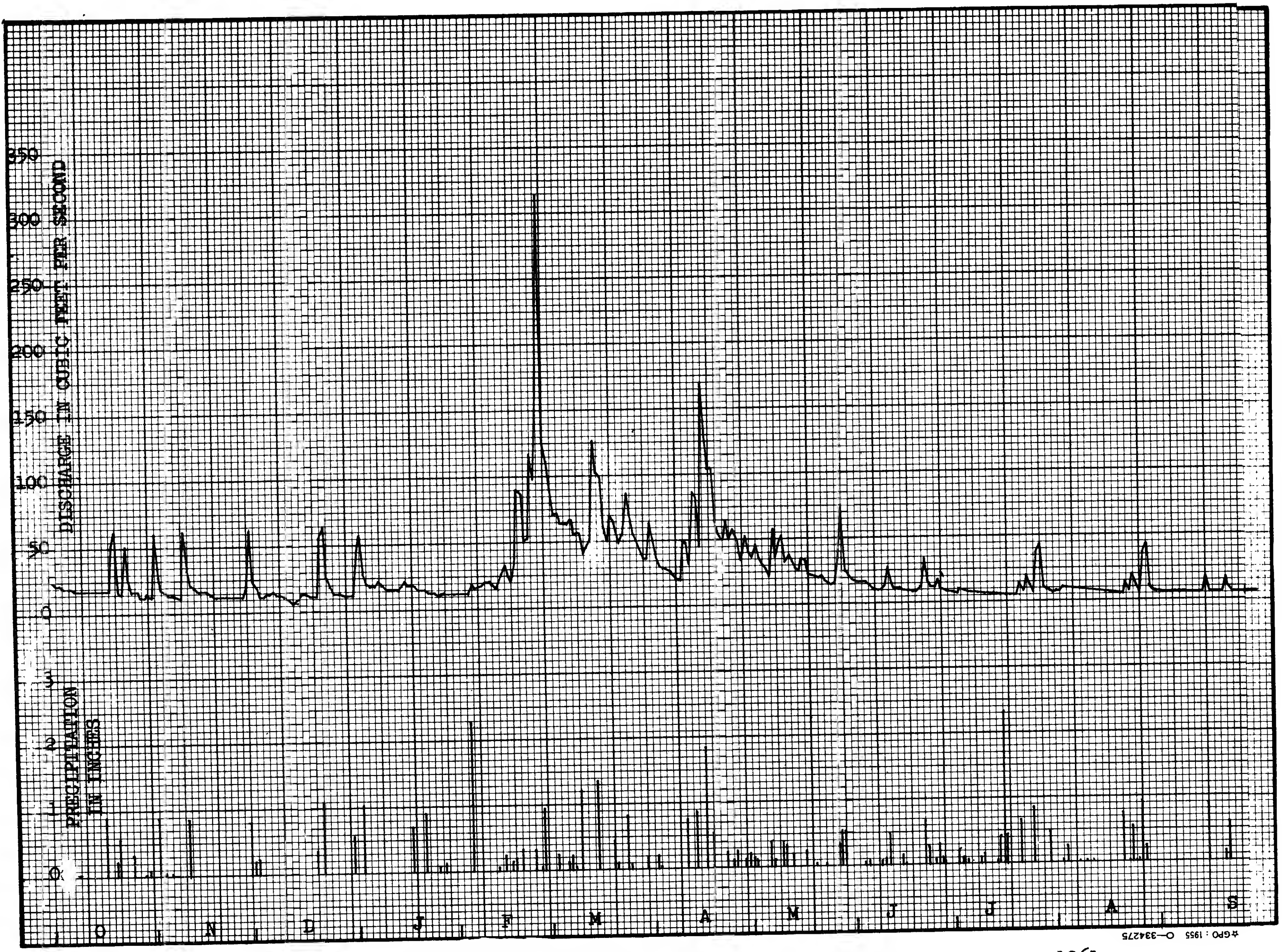


Figure 31.-- Variation in streamflow, Hackensack River at Brookside Park, water year 1961.

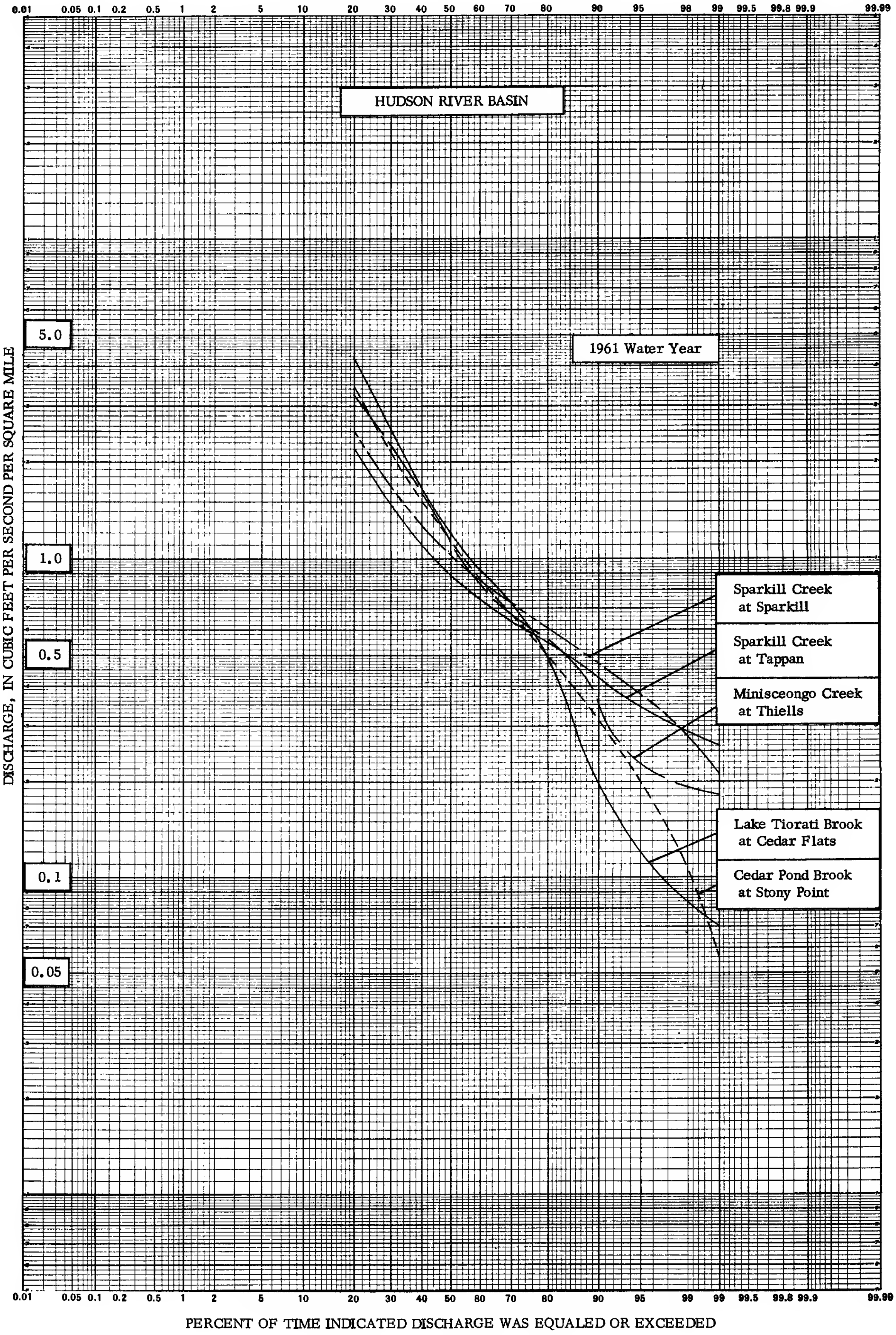


Figure 32. --Duration curves of daily flow

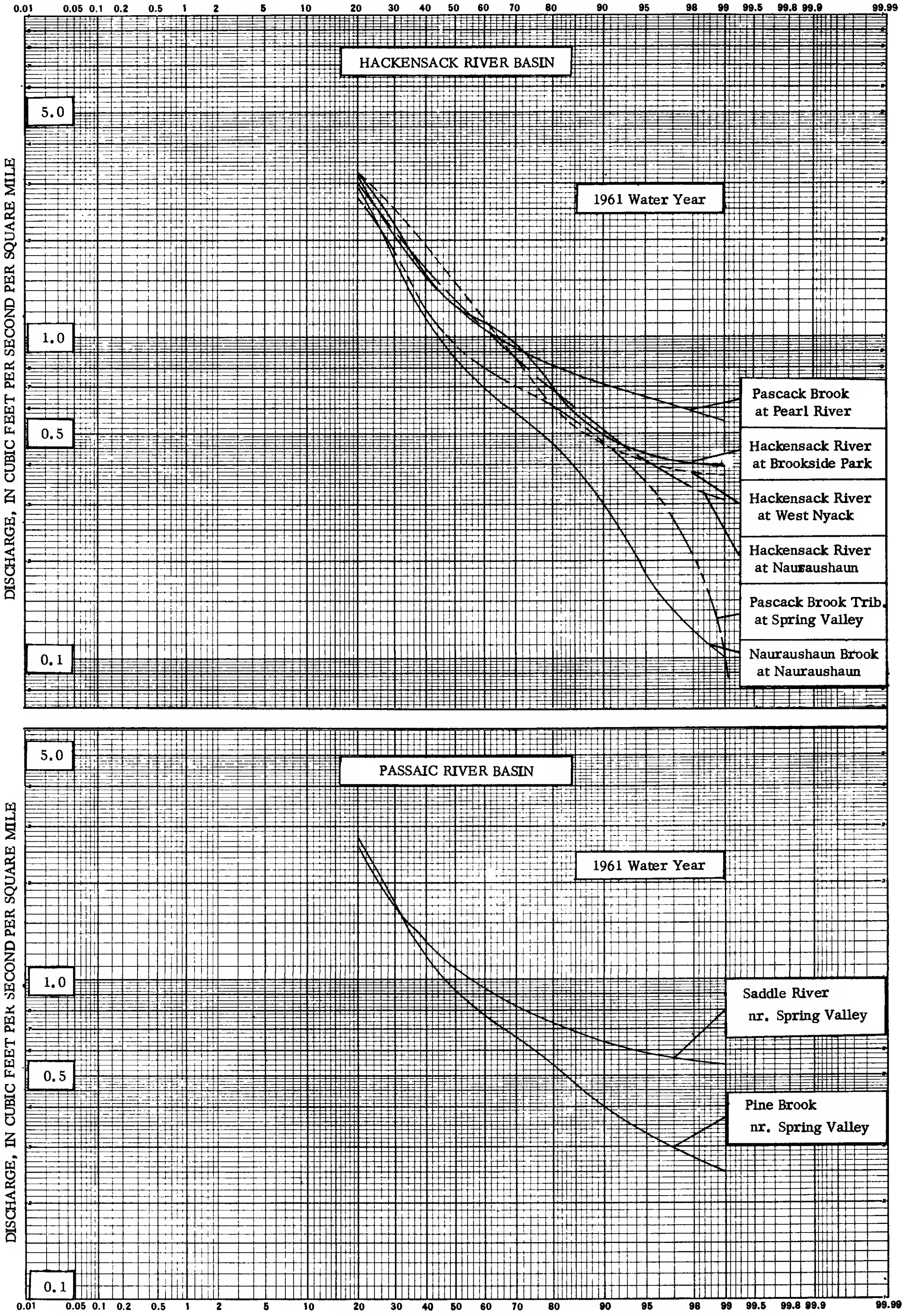


Figure 33.--Duration curves of daily flow

Note that Sparkill Creek at Tappan had the best low-water yield while the flow of Cedar Pond Brook at Stony Point falls off rapidly under the influence of diversion from the stream for public water supply. The flattening of the Minisceongo Creek curve is an indication of the mitigating effect of the swamp areas throughout the basin.

Figure 33 includes the duration curves for flow at sites in the Hackensack and Passaic basins. As in figure 32 there is a general massing of the Hackensack curves above the 70 percent level. Below this point the effect of man-made regulation is readily apparent.

Pascack Brook at Pearl River has a good low-water yield, (about 0.55 csm at 99 percent duration point, fig. 33), because of sewage effluent discharged to the stream from the Spring Valley sewage treatment plant. Hackensack River at Brookside Park has the best unregulated low-water yield, 0.4 csm at the 99 percent duration point.

Regulation by DeForest Lake is responsible for the relatively high flow (at the 99 percent point, fig. 33) on Hackensack River at West Nyack and at Nauraushaun. The curve for Pascack Brook Tributary shows the effects of low-flow regulation. That for Nauraushaun Brook indicates a very poor natural low-water flow.

In the Passaic River Basin in Rockland County, Saddle River and Pine Brook have small drainage areas, and both drain considerable swamp land. This is evidenced by the flatness of the duration curves in figure 33. The curves indicate relatively good low-water flows in both streams, but the flow is greater in Saddle River. Note how rapidly these two curves diverge below the 30 percent level.

A comparison of duration curves of daily flow, reduced to a csm basis, for streams in the Ramapo River Basin for water years 1960 and 1961 shows variation of flow with respect to time as well as geographically within the basin (fig. 34).

The curves for Ramapo River at Sloatsburg and Mahwah River at Suffern represent conditions of natural or unregulated flow whereas that for Stony Brook reflects release of water from Sebago Lake, usually starting in mid-September. During the 1960 water year such release continued until mid-November and the water surface of the lake was lowered 11 feet. In the 1961 water year the lake surface was lowered only about two feet.

The curve for Ramapo River near Mahwah represents the integrated flow of Mahwah River, Ramapo River at Sloatsburg and Stony Brook. Because water from Sebago Lake is released to Stony Brook the integrated flow also includes this release.

Comparison of the yield of streams in a given area by means of a study of the unit runoff in cubic feet per second per square mile on a month-to-month basis often sheds light on the relative value of the several streams for one or more uses. Such a comparison has been made for Rockland County and is reflected in tables 37 and 38.

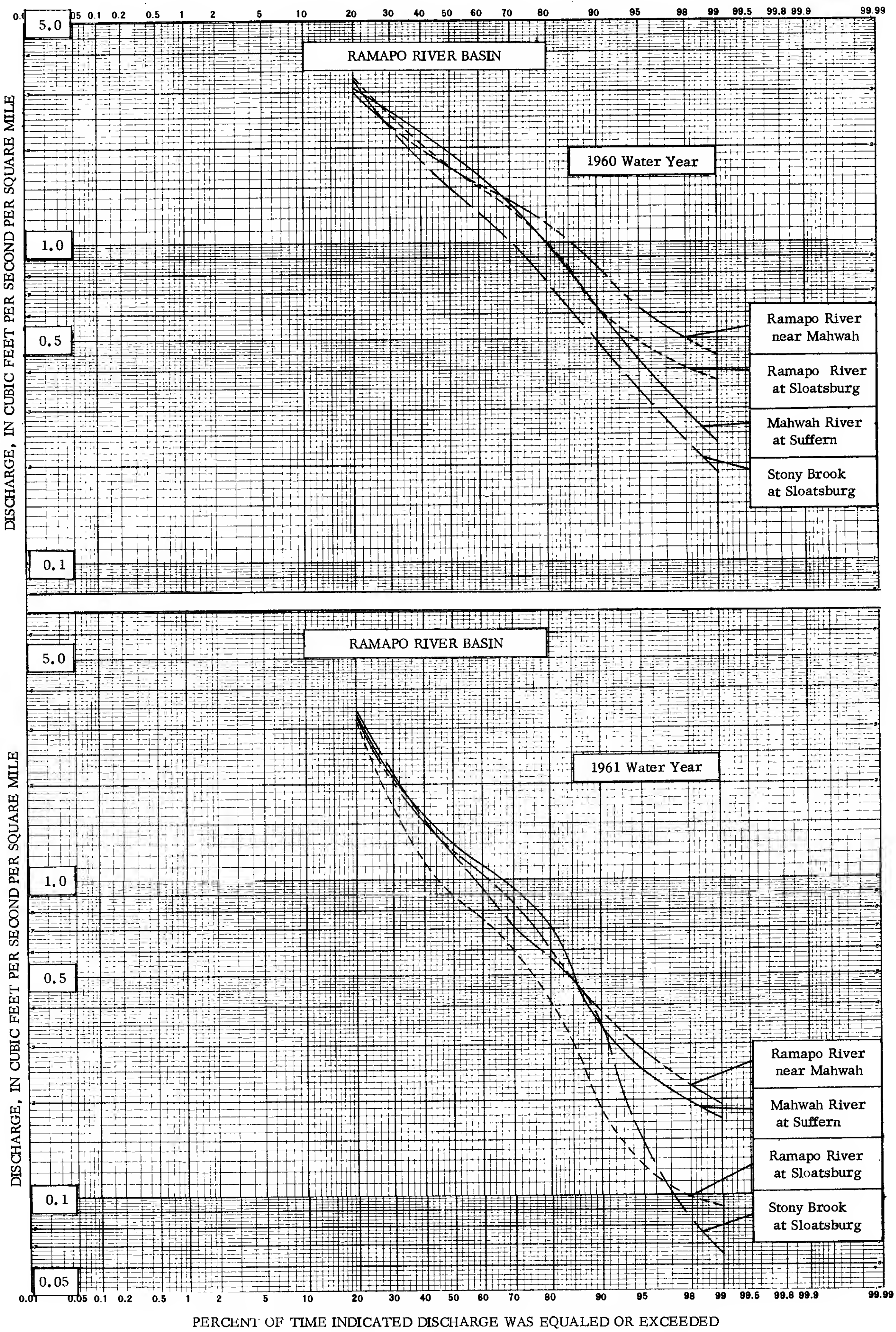


Figure 34. --Duration curves of daily flow

Table 37 is the runoff study for unregulated streams. For both water years, the unit yield from Lake Tiorati Brook was highest and that from Pine Brook the lowest. Hackensack River at Brookside Park produced almost the same total runoff for each of the two years (2.06 csm and 2.05 csm, respectively) and yet the precipitation at Spring Valley totaled about 14 1/2 inches more in 1960 than in 1961. Distribution of the flow in Hackensack River on a month-to-month basis was more uniform in 1960 than in 1961 when a bulk of the runoff occurred in February, March and April.

Further study of tables 37 and 39 shows that Hackensack River Basin above Brookside Park experienced heavy water losses (the difference between precipitation and runoff) in October 1959 and July 1960. The losses in May, June, August and September 1960 also were greater than normal. Since these so-called water losses are, for the most part, the result of evaporation from the land and water surfaces, and evaporation and transpiration from vegetation, the losses usually increase as the amount of available moisture increases. Thus wet months during the growing season often result in high water losses.

In 1961, rainfall during the growing-season months was in general normal to below normal resulting in smaller losses by evapo-transpiration and, consequently, a larger percentage of the rainfall appeared as surface runoff. It is also quite possible that several inches of the 1960 precipitation penetrated the soil and reached the ground-water reservoir to be released at a later date, possibly in 1961, as ground-water contribution to surface runoff.

The conditions described in the previous two paragraphs are specifically those in the upper Hackensack River Basin but are typical of those prevailing throughout Rockland County in 1960 and 1961.

Table 38 is a similar runoff study for streams in the county subject to seasonal regulation. This table shows that Stony Brook produced the highest unit runoff for the two-year period. Minisceongo Creek showed no difference in the annual figures, even though this basin received more than 13 1/2 additional inches of precipitation in 1960 than in 1961.

Except for the effect of DeForest Lake on the flows in Hackensack River below West Nyack the effect of regulation on Rockland County streams is relatively small except during low-flow periods. The diversions for water supply from Cedar Pond Brook, Minisceongo Creek, and Tributary to Ramapo River at Sloatsburg are relatively small parts of the average flow of these streams. Regulation on other streams may cause some variation from natural flow during individual months but the annual figures usually approximate natural flow.

Table 37. - Summary of monthly runoff, unregulated streams

1960 Water Year

	Drainage area	cfs/sq. mi.												
		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Year
Hackensack River at Brookside Park	13.2	1.32	1.52	2.91	2.49	3.61	1.86	2.87	1.41	.848	1.48	1.97	2.57	2.06
Lake Tiorati Brook at Cedar Flats	10.5	2.00	2.89	4.14	3.07	4.30	2.21	4.41	1.78	.804	1.41	3.12	3.12	2.76
Mahwah River near Suffern	12.3	1.23	1.99	3.37	2.77	3.80	2.20	4.05	1.90	.810	1.15	2.59	2.60	2.37
Int. Area	8.32	1.23	1.65	2.75	2.74	3.34	2.21	3.38	2.10	1.08	1.08	2.04	2.63	2.19
Mahwah River at Suffern	20.7	1.22	1.85	3.11	2.75	3.60	2.19	3.77	1.98	.913	1.13	2.36	2.61	2.28
Nauraushaun Brook at Nauraushaun	6.08	--	--	--	--	4.90	1.73	3.22	1.23	.382	1.44	2.20	2.50	--
Pine Brook near Spring Valley	2.28	1.14	1.25	1.92	2.27	3.34	1.73	2.64	1.20	.461	.982	1.53	1.93	1.69
Ramapo River at Sloatsburg	60.9	1.61	2.43	3.20	2.66	3.46	1.94	4.50	1.30	1.06	1.79	4.38	3.71	2.66

1961 Water Year

	Drainage area	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Year
Hackensack River at Brookside Park	13.2	1.61	1.53	1.23	1.40	4.20	4.85	4.27	2.36	1.02	1.02	.752	.508	2.05
Lake Tiorati Brook at Cedar Flats	10.5	.702	1.71	1.40	1.50	4.57	5.84	5.81	3.80	1.39	.598	1.21	.459	2.35
Mahwah River near Suffern	12.3	1.24	1.48	1.46	1.50	4.38	5.43	5.11	2.68	1.16	.837	.653	.383	2.18
Int. Area	8.32	1.38	1.20	1.16	1.36	2.69	4.77	4.05	2.73	1.11	.826	.514	.331	1.84
Mahwah River at Suffern	20.7	1.29	1.36	1.33	1.44	3.69	5.17	4.66	2.69	1.14	.826	.549	.361	2.03
Nauraushaun Brook at Nauraushaun	6.08	1.03	1.47	.977	1.15	3.42	4.16	3.77	1.96	.607	1.10	.750	.610	1.74
Pine Brook near Spring Valley	2.28	.860	.912	.697	1.02	3.00	4.52	4.21	2.24	.961	.961	.583	.535	1.70
Ramapo River at Sloatsburg	60.9	.852	.870	.969	1.00	4.40	5.42	4.89	2.86	1.12	.384	.218	.264	1.92

Table 38. - Summary of monthly runoff, streams with seasonal regulation

1960 Water Year

	Drainage Area	cfs/sq. mi.												
		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Year
Minisceongo Creek	15.0	1.61	2.05	3.38	2.49	3.05	1.55	2.98	1.42	.640	1.02	1.87	2.64	2.05
Pascack Brook Tributary	4.58	.954	.959	1.89	1.87	2.55	1.61	2.71	1.28	.762	1.62	1.98	2.25	1.70
Saddle River	2.06	--	--	--	--	--	--	--	--	--	1.52	1.66	1.79	--
Stony Brook	18.2	3.27	.659	1.48	3.15	3.90	2.16	4.37	1.48	.797	1.84	3.98	4.40	2.62

1961 Water Year

Minisceongo Creek	15.0	3.21	1.50	1.07	1.12	3.05	5.87	3.81	2.21	.907	.920	.687	.293	2.05
Pascack Brook Tributary	4.58	1.26	.963	.797	.856	2.58	3.54	3.43	2.27	.954	1.18	.793	.620	1.60
Saddle River	2.06	.990	1.14	.932	1.21	2.60	3.67	3.58	2.07	1.11	1.19	.966	.757	1.68
Stony Brook	18.2	.984	1.44	1.45	.852	5.10	6.21	5.82	2.77	1.18	.736	.318	1.00	2.30

CONCLUSIONS

By now the study of creeks, brooks and rivers in Rockland County has reached a point where a considerable amount of valuable informative data have been acquired. The history of the flow in the major streams has been written for a two-year period (a relatively short span in the life of a stream). By correlation processes, the regimen of flow of some of the streams has been projected back to cover a twenty-five year period. If conditions were not changing or about to change, reliable predictions of the future behavior of many of the streams could be made.

Surface water in Rockland County appears to have considerable potential that should contribute to the solution of future water-supply problems. What the actual potential is or will be is difficult to state precisely at this time because of the short periods of record. But, the water situation generally appears favorable. During the 1961 water year, the total average flow of surface water was 1.18 million gallons per day per square miles of drainage area, or about 210 million gallons per day from the total land surface of 173 square miles in the County. This was almost 10 times the estimated use of water in the County during that period.

Whether this favorable situation will continue will depend to a large extent on the weather. Precipitation throughout the County is highly variable during individual storm periods as well as on a daily, monthly, or annual basis. The long-term averages at three stations vary from 45 to almost 51 inches of precipitation per year, the greater amount usually occurring in the northern and western parts of the County and the smaller in the southeastern section.

Under such conditions of varying precipitation, there may be periods when the quantity of water available would be less than needed. In 1961, the low-water yield of gaged streams was about 22.7 cfs or slightly less than 14.7 million gallons per day. This was less than 70 percent of the average usage of 21.9 million gallons per day but slightly more than the 11.1 mgd drawn from surface water sources. It also was considerably less than that needed during periods of very little precipitation, when usage generally exceeds the average.

But there are other factors that have to be considered in appraising the water situation in the County. In presenting the favorable side of the picture the assumption is that every drop of water will be available. This is impossible. About 40 percent of the precipitation (potential surface-water supply) is lost by transpiration and evaporation. Some of the streams are badly polluted and the water would be available only after extensive treatment. Then, too, all the water cannot be appropriated. In some streams, certain minimum rates of flow need to be maintained to reduce the concentration of pollution. The major streams are interstate streams and it appears improbable that the entire flow of such streams would be appropriated without consideration of the downstream uses.

Because the total flow is unavailable and during dry periods is less than water used at the present time and way below the estimated need in 1980, some form of storage will be required to provide an adequate water supply.

So far, the availability of surface water has been discussed. What is the chemical quality of surface water in Rockland County?

Based on mineral content (no appraisal was made of the sanitary quality), the chemical quality of most surface waters in Rockland County appears to be satisfactory for many uses - public water supply, industrial, agricultural, and recreational. Usually the dissolved-solids content was moderate. In the Ramapo River basin it was very low - usually less than 50 ppm. The hardness in water from streams in the County ranged from soft to hard. The latter condition was particularly apparent in streams in the Pascack River basin. For some sensitive industrial processes and even for public water supply, the dissolved solids and hardness would have to be reduced.

FUTURE PROBLEMS

FUTURE PROBLEMS

Effects of Highway Construction

One of the most significant factors in the urbanization process in Rockland County will be that of road and highway construction. The expansion of residential areas as well as industrial areas requires mile after mile of arterial highways as well as many more miles of secondary roads, service roads, streets, sidewalks and driveways (fig. 35). Each square foot of paved or otherwise compacted area replaces just so much porous area for infiltration of falling rain or melting snow and diminishes recharge of ground-water reservoirs.

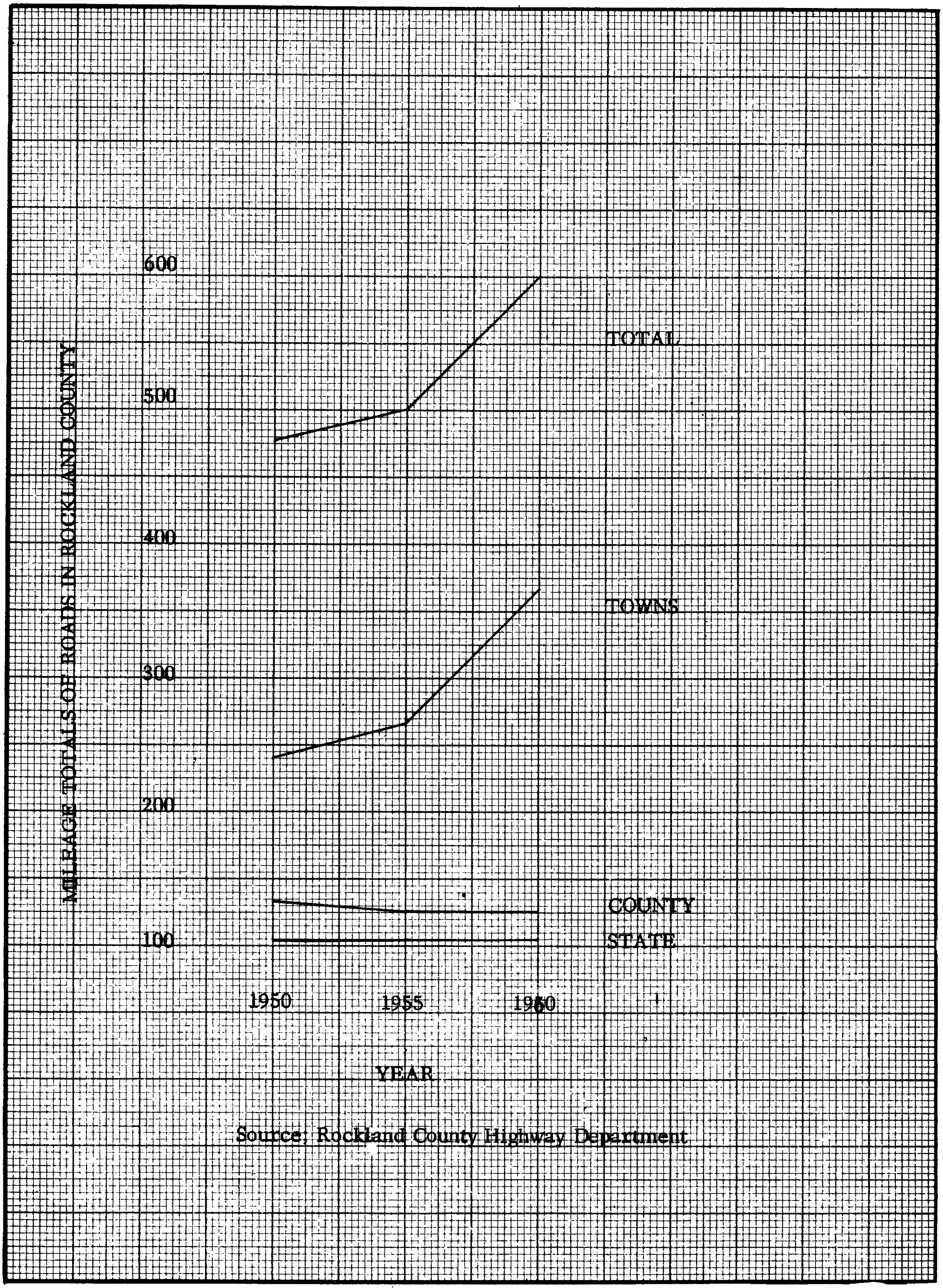
Unless other provisions are made, rain falling on these impervious areas runs off rapidly in ditches and concentrates in the streams. Little opportunity is offered for infiltration. Under such conditions culverts and bridge openings gradually become inadequate to pass the peak flows generated and backing up of water may take place at the culvert or bridge approaches. Larger openings to pass the water often become necessary and, frequently, costly.

As additional roads are built, the number of waterway crossings increases. Each crossing must be designed with care. Too large openings are costly; too small openings create backwater problems; furthermore structures may be damaged or destroyed.

During the construction of streets and highways a large amount of excavation often is necessary. Some of the soil, often the most valuable part, soon becomes sediment to be transported in suspension, or rolled along the streambed to a new resting place, often where it is not wanted.

Several remedies for conditions creating sediment problems have been tried, some more or less successfully. Lagooning of sediment-laden water in places where sufficient detention can be accomplished helps to settle out much of the sediment and thus reduces the load carried down stream. Spreading of straw or similar material on highway cuts and fills or on any area where newly disturbed soil is exposed to the pelting of falling rain helps to maintain the soil in place.

Often when highways of considerable size, such as the New York State Thruway, are constructed, they cut across natural drainage courses and the patterns of small basins are materially changed. Berm ditches have sometimes diverted water from one stream to an adjacent stream. When diversion of this type takes place, problems of too much water in some places and too little in other places often arise. Streams and swamps form because water follows the laws of nature. Any disruption of this process requires adjustments which in turn can create problems. Consequently, caution should be exercised at all times to leave drainage courses in their natural state as near as possible, although temporary periods of disruption may be necessary.



Source: Rockland County Highway Department

Figure 35. --Total miles of roads, Rockland County

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Other Effects of Urbanization

As indicated several times previously in this report, urbanization has a number of significant effects on the surface-water hydrology of an area. Although available data are insufficient to evaluate the effects of urbanization on Rockland County streams, it is expected that the situation will parallel that which has occurred and is continuing to occur in other parts of the Country.

The physical aspects of urbanization give rise to problems of increased flood potential, possible reduction in low flows, need for larger drainage structures, channel realignment, and the need for ponding areas.

Other problems associated with urbanization include the need for additional water supply, waste disposal, sediment control, flood-plain zoning, and adequate provisions for recreation. Unfortunately the solution of some of the problems requires decisions that could amplify the size of other problems.

For example, solution of the problems associated with expansion of public water supply requires advance planning. New urban areas should not be permitted until there is assurance that a satisfactory water supply is available. But, can a public water supply utility afford to expand its facilities unless it knows how much more water will be needed and where? Perhaps because of local conditions, a new source of water supply will be needed. Development of new sources is time consuming. So, with one eye on the present and the other looking to the future, a decision must be made whether to expand an already extant public supply? Develop a new public supply? Develop private supplies? Use surface water or ground water?

The Rockland County Planning Board (1961 Data Book, pg. 50) has estimated population growth by towns up to the year 1980. According to this estimate, the Town of Clarkstown, 1960 population about 33,000, will expand in 1980 to about 98,000 persons. This township, occupying the east-central portion of the County, contains no large population centers at present. In 1961, about 5,000 acres out of a total of 25,000 acres were classed as residential with 11,000 acres classified as vacant and agricultural. Most of the town lies below elevation 600 feet and a large portion of it between 100 and 300 feet above sea level.

DeForest Lake lies wholly within the Town of Clarkstown with normal water surface at elevation 85 feet. Distribution of water from this source would not be a serious problem and the surface-water supply based on the streamflow record below the reservoir would be ample to serve the needs of the estimated 1980 population.

The second largest growth within the County is that estimated for the Town of Ramapo where an increase of from 35,000 in 1960 to 96,000 in 1980 is estimated by the Planning Board. This township includes the rather densely populated areas of Spring Valley and Suffern. The land surface lies for the most part between elevations 300 and 600 feet. Practically the entire area is now supplied from ground-water sources, although surface-water supplies serve some of the western parts of the town. Both the Ramapo and Mahwah Rivers flow through the town. The combined average flow of these two streams is ample to meet the needs of the estimated 1980 population of 96,000. However, some storage would be needed if surface water became the sole supply, since, for about 15 percent of the time, flow of these two streams could be expected to fall below the demand for water by a population of 96,000.

The population of the Town of Orangetown in 1980 is estimated by the Planning Board as twice that of 1960, an increase from 43,000 to about 87,000. Much of this increase is expected in the vicinity of Pearl River. Surface-water supplies in this township are limited. Pascack Brook and Sparkill Creek could supply limited amounts of water for industrial cooling and some forms of processing. Water from these sources might need considerable treatment before being used for processes demanding high quality water. Surface water for domestic use could be obtained most efficiently from DeForest Lake in the Town of Clarkstown.

The population of the towns of Stony Point and Haverstraw are expected to increase by 62 and 52 percent, respectively, between 1960 and 1980. Both of these towns are at present dependent to a large extent on surface-water supplies. Expansion of present facilities is limited. Additional storage could be provided in both the Cedar Pond Brook and Minisceongo Creek basins but this would be limited because of present demands on the headwaters of these streams by Letchworth Village and Palisades Interstate Park.

There are other sources of surface water in these towns which could be developed at least as auxiliary supplies. These include Doodletown Brook (page 101), the upper reaches of Stillwater Brook (table 50) where a reservoir might be constructed to retain spring runoff for use in the summer and fall months and Aubrey's Pond outlet (table 50) where additional storage facilities might be constructed.

Pollution

Hand in hand with the problems of additional public water supply are those of extended waste disposal facilities. Chief among these is the tremendous cost of sewage collection lines and treatment plants. This cost is greatest when suitable surface-water streams are not immediately available for the dilution of treatment plant effluents. When such conditions exist, long trunk sewers may be built to dispose of water into, possibly, the Hudson River. However, such large volumes of reusable water will then be lost to the County. The alternative is to construct treatment facilities on smaller streams closer to the source of waste water.

Fig. 36.--Pollution in Pascack Brook

Stream pollution is already a problem in the County; Sparkill Creek and other streams are used for the transport of domestic and industrial wastes. As urbanization and industrial expansion take place the problem will become worse unless steps are taken to correct the condition. One hundred percent elimination would be an ideal; but it may never be realized.

But stream pollution is not a thing apart by itself. It can also contaminate ground-water sources. Perlmutter (1959, p. 56) reports that one of the principal sources of additional ground water is stratified drifts. The important characteristic of this aquifer is that it is hydraulically connected with streams and ponds. As pumpage increases, more water will be withdrawn from the surface waters. If they are polluted, then the ground-water source may also become polluted.

The physiography of Rockland County lends itself to consideration of one or more large trunk sewers leading to large treatment plants on the banks of the Hudson River. However, sewage discharged directly into the Hudson River would consist, to a large extent, of water which would be lost entirely in so far as re-use in the County is concerned. Effluent from the Spring Valley Sewage Treatment Plant is returned to Pascack Brook for re-use within the County or by residents of Northern New Jersey. The same situation exists at Suffern where effluent is returned to the Ramapo River for re-use. The process of returning sewage effluent to a stream so that it can be used downstream is definitely a form of good conservation practice.

Changes in Streamflow Regimen

As suggested earlier in this report, one of the most serious effects of urbanization is the change in streamflow regimen. Under conditions of vegetal cover throughout a watershed, a balance develops between precipitation that is intercepted, transpired, runs off as surface flow, enters the soil to satisfy soil-moisture deficiency, or infiltrates the ground until it reaches the ground-water reservoir.

The distribution of rainfall or snow melt into these various categories varies from time to time according to antecedent conditions. The distribution also varies throughout the various parts of the basin. However, the sum total of the distribution remains fairly uniform as long as no significant changes take place in land use.

Any man-made change in the land use throughout a basin has definite effects on the water that leaves the basin as surface-water flow. In the process of urbanization, a marked effect on the streamflow regimen gradually takes place when impervious layers such as house roofs, sidewalks and driveways replace pervious soil. A considerably larger part of the falling rain or melting snow races along gutters, ditches and storm sewers as surface runoff. This runoff reaches stream courses quickly and increases the quantity of flow in the streams. Under urbanizing conditions, therefore, peak flows or flood flows generally become increasingly greater. Unless large storage facilities are provided for these flood flows, the water is soon lost to the ocean; in fact, gone forever as far as County use is concerned.

While this is taking place, less of the precipitation may reach the ground-water reservoirs to increase the supply available for pumpage or to feed the streams during periods of base flow when no surface runoff is available.

Urbanization tends to increase peak flows in a basin and may possibly decrease low flows to the point where even perennial streams go dry from time to time and for increasing periods of time.

It is quite possible that the total flow from a basin is not seriously altered by urbanization but it is expensive to try to utilize the total flow by construction of massive storage areas. Likewise it is highly inconvenient to have an increasing number of floods and droughts on what was once considered a relatively placid stream.

Certain provisions can be made, during the process of urbanization, to keep the streamflow pattern in a basin as near to normal as is feasible and economical. If the concentration of houses within a development is kept at a minimum, more of the pervious areas will remain, increasing the chance for infiltration. Ponding areas including natural depressions of a swamp character are effective in lowering peak discharges and providing time for infiltration.

Man-made ponding areas, often called recharge basins, may be constructed to receive storm water runoff and delay its passage downstream, permitting infiltration to ground-water reservoirs. This type of project is effective only when the recharge basin is underlain with pervious soil; otherwise only a stagnant pool results.

Regulatory structures may be constructed on the smaller tributaries of a basin at the higher elevations to detain flood flows for release at a later time when the peak has passed. This type of structure may be self-operating, that is, with a fixed opening permitting only a limited amount of discharge. Peak discharges thus are lowered but the remainder of the contents of the pond is drained within a few hours.

A manual type of retention facility may be more desirable in which flood flows are retained for release at some later date by manipulation of gates or valves. A certain amount of low-flow improvement can result from this type of operation. But careful design is essential so that the structures are not damaged or destroyed by an unusually large flood where the capacity of the retaining structure or its spillway are exceeded.

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DEFINITION OF TERMS AND ABBREVIATIONS

The terms of streamflow and other hydrologic data, as used in this report, are defined as follows:

Gaging station is a particular site on a stream, canal, lake or reservoir where systematic observations of gage height or discharge are obtained. When used in connection with a discharge record, the term is applied only to those gaging stations where a continuous record of discharge is obtained.

Partial-record station is a particular site where limited streamflow data are collected systematically over a period of years for use in hydrologic analyses.

Cubic foot per second (cfs) is the rate of discharge of a stream whose channel is 1 square foot in cross-sectional area and whose average velocity is 1 foot per second.

Cubic feet per second per square mile (cfsm) is the average number of cubic feet of water flowing per second from each square mile of area drained, assuming that the runoff is distributed uniformly in time and area.

Runoff in inches (in.) shows the depth to which the drainage area would be covered if all the runoff for a given time period were uniformly distributed on it.

Cfs-day is the volume of water represented by a flow of 1 cubic foot per second for 24 hours. It is equivalent to 86,400 cubic feet, 1.93347 acre-feet, or 646,317 gallons, and represents a runoff of 0.0372 inch from 1 square mile.

Stage-discharge relation is the relation between gage height and the amount of water flowing in a channel, expressed as volume per unit of time.

Control designates a feature downstream from the gage that determines the stage-discharge relation at the gage. This feature may be a natural constriction of the channel, a long reach of the channel, or an artificial structure.

Contents is the volume of water in a reservoir or lake. Unless otherwise indicated, volume is computed on the basis of a level pool and does not include bank storage.

The drainage area of a stream at a specified location is that area, measured in a horizontal plane, which is so enclosed by a topographic divide that direct surface runoff from precipitation normally would drain by gravity into the river above the specified point. Figures of drainage area given herein include all closed basins, or noncontributing areas, within the area unless otherwise noted.

Dissolved solids residue from a clear sample of water after evaporation and drying of residue for one hour at 180°C.

Hardness generally considered as the property of water attributable to the presence of alkaline earth metals of which calcium and magnesium are the principle ones. Hardness is expressed in terms of calcium carbonate equivalent of the carbonate and bicarbonate content of water. The hardness in excess of this amount is called noncarbonate hardness.

Mineral Content. Used in this report as equivalent to dissolved solids.

Parts per million (ppm) equivalent to one milligram of solute in 1 kilogram of solution.

pH the negative logarithm of the hydrogen-ion concentration. Water having a pH of 7 is considered neutral being neither acid or alkaline. Values higher than 7 indicate increasing alkalinity, and values less than pH7 denote increasing acidity.

Specific conductance the reciprocal of specific resistance. Specific conductance indicates the ability of water to conduct an electric current and is expressed as micromhos at 25°C. This property is related to the quantity and kind of dissolved mineral matter in solution and, within rather wide limits, is an approximate measure thereof.

Base-flow or base runoff - sustained or fair weather runoff. In most streams base runoff is composed largely of ground-water effluent.

Duration curve: A cumulative frequency curve that shows the percentage of time that specified discharges are equaled or exceeded.

Million gallons per day (mgd) - equal to 1.55 cubic feet per second. 1 cfs equals about 0.646 mgd.

Water year - The 12-month period, October 1 through September 30. The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months.

APPENDIX

Table 39. - Monthly and annual precipitation in inches, Letchworth Village, N. Y.

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1940	--	--	--	3.69	3.21	7.03	6.29	6.99	4.14	3.68	4.73	3.33	--
41	3.98	5.23	3.65	2.40	3.36	1.58	2.49	1.92	4.41	4.99	4.18	.58	38.77
42	3.20	4.82	4.70	4.45	2.49	6.10	1.27	3.42	4.38	7.10	7.90	7.04	56.87
43	4.31	6.14	6.56	3.53	2.64	3.54	3.31	4.79	3.98	4.66	2.49	3.80	49.75
44	10.71	4.31	1.22	3.28	3.02	6.45	4.74	2.57	3.54	1.97	3.34	5.46	50.61
1945	1.66	6.81	4.10	3.32	2.95	2.47	4.55	7.83	4.14	13.63	4.71	8.31	64.48
46	2.69	5.65	5.99	1.32	2.37	2.49	2.02	8.02	3.68	7.78	3.50	7.04	52.55
47	2.22	1.40	2.78	3.56	2.20	4.02	6.17	7.62	6.36	5.94	2.36	1.81	46.44
48	1.58	8.04	3.69	3.41	1.82	3.22	4.87	5.93	3.34	5.87	2.10	.88	44.75
49	1.66	5.93	7.11	6.43	1.93	1.90	4.47	5.64	.52	3.49	4.64	4.76	48.48
1950	1.40	1.74	3.46	3.27	4.81	4.09	2.32	4.90	3.19	6.46	4.27	2.15	42.06
51	2.02	4.91	6.57	4.10	3.85	9.07	3.14	4.25	3.31	4.03	4.62	1.32	51.19
52	4.23	5.31	4.05	4.69	3.25	4.59	8.48	5.72	6.03	4.61	8.65	6.71	66.32
53	.44	5.32	5.28	6.49	2.10	9.29	6.10	4.34	2.39	4.02	.92	1.47	48.16
54	3.43	2.00	5.50	1.73	2.37	3.72	3.58	5.80	1.38	2.92	9.70	7.82	49.95
1955	1.61	6.85	4.18	1.71	3.74	3.97	3.19	1.41	3.69	4.42	13.79	3.06	51.62
56	13.67	4.44	.68	2.21	4.18	4.53	4.87	3.04	3.43	7.08	2.65	4.83	55.61
57	3.54	3.31	4.93	2.16	3.45	2.91	3.90	2.08	1.38	3.01	2.58	2.65	35.90
58	4.32	3.34	7.92	6.04	6.44	4.95	6.07	4.59	3.11	3.13	4.04	6.26	60.21
59	5.99	3.54	1.39	2.20	2.31	4.41	3.14	2.81	4.57	4.72	4.68	1.46	41.22
1960	6.62	4.06	5.11	3.18	4.81	2.63	4.00	4.38	2.81	9.17	6.09	7.74	60.60
61	1.81	2.93	2.82	3.50	3.13	5.09	6.45	5.11	3.12	6.23	4.29	2.44	46.92
Sum	81.09	96.08	91.69	76.67	70.43	98.05	95.42	103.16	76.90	118.91	106.23	90.92	1062.46
Ave	3.86	4.58	4.37	3.48	3.20	4.46	4.34	4.69	3.50	5.40	4.83	4.13	50.59

Table 40. - Monthly and annual precipitation in inches at Sparkill, N. Y.

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1940	--	--	--	2.48	2.40	5.59	6.45	5.87	3.71	2.67	4.72	3.15	--
41	2.83	3.85	2.73	3.79	2.66	2.66	2.22	2.92	4.16	6.23	6.54	.34	40.93
42	2.14	2.61	4.58	2.43	2.85	6.62	1.46	2.77	2.59	6.55	10.67	3.57	48.84
43	3.19	4.34	4.99	2.93	1.73	2.73	2.25	4.35	3.33	6.91	2.66	2.00	41.41
44	8.50	3.15	1.37	2.85	2.10	5.47	5.44	2.51	3.12	.75	3.68	9.86	48.80
1945	2.33	6.38	3.70	2.80	2.60	2.37	3.73	5.27	2.99	9.04	5.00	4.46	50.67
46	1.89	4.71	4.52	1.62	1.86	2.36	1.25	9.03	3.46	5.58	6.36	4.42	47.06
47	1.67	1.37	1.73	2.33	1.96	3.08	4.41	7.14	4.74	3.87	2.61	2.87	37.78
48	1.25	7.46	2.79	3.40	1.41	4.38	3.62	6.15	4.71	3.13	2.85	.34	41.49
49	2.18	3.94	5.00	5.71	2.91	2.40	4.27	3.69	.21	4.04	2.93	3.72	41.00
1950	1.46	1.18	3.53	2.73	4.04	3.27	1.97	3.02	1.43	5.29	3.35	1.32	32.59
51	1.79	5.58	5.53	3.18	4.57	7.61	2.64	3.89	3.77	5.16	6.60	2.18	52.50
52	4.76	7.96	5.22	5.02	1.89	4.32	7.34	5.14	4.27	4.01	7.01	6.29	63.23
53	0.96	4.34	4.15	5.60	1.99	9.43	5.17	3.16	2.42	4.98	2.17	1.71	46.08
54	3.89	1.95	4.75	1.74	1.94	3.70	3.72	4.67	1.34	1.39	6.33	8.90	44.32
1955	1.70	6.78	3.98	.76	3.03	4.35	2.68	2.42	4.19	2.51	10.89	3.00	46.29
56	10.34	4.46	.37	2.32	4.05	3.62	3.38	2.89	4.24	5.64	2.61	3.80	47.72
57	1.40	4.46	4.60	2.23	2.34	2.87	5.59	2.61	2.00	3.48	2.53	3.39	37.50
58	3.42	3.20	6.96	5.55	3.14	4.44	6.44	4.15	2.13	2.51	3.21	3.99	49.14
59	5.67	3.45	1.15	2.42	1.94	3.42	3.19	1.79	5.63	3.06	3.61	2.64	37.97
1960	6.87	4.70	4.84	3.21	4.81	2.03	3.68	3.91	1.55	8.23	6.11	7.16	57.10
61	1.61	2.78	3.23	2.94	2.83	4.53	5.65	2.72	1.90	7.57	6.23	2.23	44.22
62	1.90	3.11	3.75	--	--	--	--	--	--	--	--	--	--
Sum	71.75	91.76	83.47	68.04	59.05	91.25	86.55	90.07	67.89	102.60	108.67	81.34	1002.44
Ave	3.26	4.17	3.79	3.09	2.68	4.15	3.93	4.09	3.09	4.66	4.94	3.70	45.57

Table 41. - Monthly and annual precipitation in inches at Spring Valley, N. Y.

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1940	--	--	--	3.76	2.72	6.19	6.34	6.07	4.02	2.60	4.90	3.35	--
41	3.29	4.92	3.61	2.95	2.64	2.34	2.34	2.16	3.90	6.84	3.89	.42	39.30
42	2.33	3.06	4.62	2.63	3.84	6.08	1.31	3.10	3.02	6.47	10.18	5.35	51.99
43	3.38	4.67	4.90	3.15	1.72	3.45	2.73	3.98	3.63	5.22	2.67	2.72	42.22
44	9.41	4.52	1.12	3.36	2.49	6.23	5.81	1.92	3.51	2.74	2.60	6.55	50.26
1945	1.33	6.33	3.81	3.18	3.35	2.37	3.97	6.80	4.61	14.07	4.28	6.03	60.13
46	2.02	4.81	5.14	1.57	2.17	2.79	1.14	7.03	4.03	7.45	5.23	4.94	48.32
47	1.78	1.20	2.08	2.83	1.37	3.78	4.33	7.02	5.30	4.11	3.51	1.33	38.64
48	1.05	8.06	3.39	3.66	1.64	3.06	4.23	6.63	4.98	5.98	3.86	.34	46.88
49	2.24	4.05	6.02	5.88	2.76	2.00	4.50	4.55	.46	3.22	4.95	3.12	43.75
1950	2.11	1.22	3.47	3.05	4.70	4.02	2.02	3.88	2.29	6.43	3.93	1.49	38.61
51	1.66	6.04	5.94	3.38	5.17	8.75	2.79	4.54	3.73	5.06	6.60	1.96	55.62
52	5.11	7.03	5.36	5.12	2.64	5.36	7.80	5.57	7.80	4.39	6.99	5.31	68.48
53	.53	5.04	5.26	5.61	2.06	9.97	5.26	4.66	2.35	4.06	.87	1.48	47.15
54	3.85	2.51	5.49	1.77	2.25	3.96	3.82	5.32	1.22	1.85	9.64	8.07	49.75
1955	1.71	7.22	4.30	.88	3.57	4.28	3.26	1.68	3.60	6.47	13.38	3.15	53.50
56	13.32	3.28	.20	1.97	3.92	3.05	5.40	3.01	3.47	5.44	2.32	4.29	49.67
57	1.48	5.74	4.17	2.21	2.53	3.07	5.45	1.91	1.20	2.61	2.80	2.93	36.10
58	3.82	3.04	8.63	7.12	4.54	3.51	7.24	4.53	2.26	2.89	4.71	4.16	56.45
59	5.77	4.18	1.05	2.35	1.84	3.27	3.39	1.25	5.61	2.69	4.32	2.78	38.50
1960	7.60	4.18	4.55	3.56	4.82	1.88	4.10	3.48	2.56	9.09	6.47	6.80	59.09
61	2.93	2.74	2.36	2.81	3.57	5.20	6.06	3.82	2.89	4.88	3.95	3.42	44.63
62	1.81	3.36	3.75	2.89	4.17	2.79	5.18	--	--	--	--	--	--
Sum	76.72	93.84	85.47	72.80	66.31	94.71	93.29	92.91	76.44	114.56	112.05	79.99	1058.99
Ave	3.65	4.47	4.07	3.31	3.01	4.30	4.24	4.22	3.47	5.21	5.09	3.64	48.14

Table 42. - Monthly and annual precipitation in inches at stations with short records

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
DEFOREST LAKE (Spring Valley W.W.&S.Co.)													
1959	4.02	2.97	0.71	2.04	1.86	3.10	2.35	1.45	4.56	2.80	4.12	2.87	32.85
1960	6.30	3.75	3.70	2.80	3.40	1.19	3.05	2.96	1.68	7.01	4.12	4.73	44.69
1961	2.59	2.97	2.03	1.71	2.07	3.89	4.68	3.16	2.71	5.12	4.40	1.58	36.91
1962	1.31	1.99	2.13	2.77	2.96	.94	4.27						
SUFFERN (Suffern Water Works)													
1959	3.79	3.47	1.01	1.88	2.39	3.96	3.94	0.60	5.83	4.72	5.11	2.21	38.91
1960	7.93	4.29	5.45	3.64	3.83	2.51	3.68	4.83	2.31	7.79	5.14	7.20	58.60
1961	1.92	2.40	3.25	3.26	4.25	5.41	6.21	4.62	2.39	4.10	3.42	2.94	44.17
1962	1.81	3.15	3.01	3.45	4.99	2.18							
HACKENSACK RIVER AT BROOKSIDE PARK (USGS)													
1960	--	--	--	--	--	--	--	2.85	2.75	7.63	5.72	5.98	--
1961	2.19	2.77	2.17	2.89	4.58	4.82	5.30	3.46	2.50	5.92	2.92	1.83	41.35
CEDAR FLATS (USGS)													
1960	--	--	--	--	--	--	--	3.92	3.10	9.80	5.83	7.19	--
1961	1.68	3.06	1.09	3.67	4.19	4.82	6.42	5.41	2.32	8.19	6.37	2.56	49.78
NANUET (Rockland County Highway Dept.)													
1960	--	--	--	3.31	4.74	2.69	3.33	3.58	1.79	8.84	0.28	5.26	--
1961	2.35	2.22	3.50	3.69	4.24	5.08	6.19	3.19	3.09	3.50	3.69	3.65	44.39
NEW CITY (Rockland County Highway Dept.)													
1960	--	--	--	--	--	--	2.67	3.07	0.96	5.42	5.33	4.42	--
1961	--	--	--	--	--	--	--	3.82	2.69	5.49	3.73	2.71	--
TOMPKINS COVE (Rockland County Highway Dept.)													
1960	--	--	--	--	3.60	--	--	3.41	1.74	4.55	3.58	1.97	--
1961	1.35	2.59	1.46	--	--	--	4.54	5.44	--	3.15	6.50	1.80	--

Temperature (°F) of water, water year October 1959 to September 1960

Table 43. - Maximum and minimum daily water temperatures, Sparkill Creek at Tappan, N. Y.

47100

Day	October		November		December		January		February		March		April		May		June		July		August		September	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1							38	36	40	38	40	36	58	47	55	51	67	61	68	65	71	63	73	68
2							39	35	39	38	41	35	51	48	61	47	69	61	73	65	73	66	72	67
3							43	39	40	36	38	34	49	45	64	49	71	65	71	65	72	69	68	63
4							40	39	42	37	37	34	56	44	65	50	69	66	72	64	71	68	64	61
5							39	37	43	38	40	36	54	45	68	52	71	64	69	61	68	66	66	62
6							38	38	42	38	43	37	49	42	68	53	72	65	69	62	72	66	66	60
7							40	38	42	39	41	36	48	42	64	55	68	62	73	63	71	64	68	61
8							41	40	39	36	44	37	48	43	60	57	70	61	73	62	74	66	70	64
9							41	37	44	39	42	36	52	45	60	55	68	61	76	63	73	65	70	66
10							37	37	45	42	43	38	53	42	55	51	70	61	71	66	73	68	71	67
11					--	--	37	35	48	44	43	36	53	41	60	53	70	61	69	66	70	67	67	62
12					48	42	38	35	44	40	44	36	56	46	64	54	65	62	74	65	70	65	62	62
13					48	44	39	35	40	37	46	37	55	47	61	57	67	60	74	67	69	66	64	60
14					44	41	40	36	38	35	45	39	58	47	58	55	64	62	71	66	68	64	63	59
15					42	40	40	38	38	34	46	38	64	53	62	52	63	60	73	64	71	66	63	57
16					44	42	40	37	42	36	44	39	60	53	67	56	71	60	74	63	68	65	64	60
17					46	42	39	36	43	38	42	39	59	50	64	57	68	62	73	64	72	64	63	60
18					45	44	39	37	44	38	45	40	57	51	62	60	73	64	72	66	73	64	61	60
19					45	41	41	38	39	35	44	40	60	46	68	58	72	60	73	67	68	63	63	61
20					41	38	38	36	41	37	45	40	60	46	64	61	70	61	76	68	67	64	61	60
21					39	37	39	37	39	37	46	40	63	50	65	63	71	60	72	64	70	65	64	61
22					38	35	40	38	40	38	43	40	69	55	63	58	67	60	71	63	70	67	63	61
23					36	35	40	38	42	37	48	38	67	55	58	56	70	63	73	66	71	67	62	58
24					39	35	41	37	42	36	49	41	62	53	63	58	69	66	74	67	70	66	63	59
25					39	37	39	36	40	38	47	39	69	53	63	56	73	64	72	63	68	63	62	60
26					41	39	41	37	41	36	42	38	66	58	67	59	74	59	73	63	68	62	63	59
27					41	40	42	37	41	38	50	40	60	56	70	60	73	61	72	66	69	63	65	59
28					41	39	42	36	42	37	52	45	62	52	68	61	74	62	75	67	71	66	66	64
29					39	38	41	38	41	38	55	44	67	53	63	59	68	64	72	68	71	66	66	65
30					41	39	40	38	--	--	51	48	59	54	62	59	76	65	70	67	73	69	67	64
31					39	38	41	37	--	--	52	48	--	--	66	60	--	--	71	65	71	69	--	--

Temperature (°F) of water, water year October 1960 to September 1961

Table 43. - Maximum and minimum daily water temperatures, Sparkill Creek at Tappan, N. Y. (continued)

47100

Day	October		November		December		January		February		March		April		May		June		July		August		September	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1	64	57	55	53	41	39	37	34	37	36	40	39	46	43	50	47	64	59	77	66	72	67	74	68
2	58	54	55	51	41	38	35	34	37	35	44	40	48	42	54	50	71	61	77	66	68	66	76	69
3	61	56	52	49	45	40	36	35	36	36	47	40	46	41	60	47	67	61	72	67	67	65	75	69
4	61	57	52	49	41	39	35	34	36	35	45	42	51	42	59	48	68	57	71	63	70	65	73	68
5	62	57	52	49	44	41	35	33	36	35	47	43	52	44	63	49	70	58	69	61	68	65	74	68
6	62	60	51	46	45	41	37	35	36	35	46	44	49	46	58	52	73	62	71	63	69	65	74	69
7	61	56	46	43	45	43	39	36	38	36	50	43	51	44	56	52	71	64	69	62	72	66	70	67
8	58	53	45	41	42	38	39	37	39	36	46	37	53	44	58	54	67	61	70	65	70	65	69	67
9	57	52	48	44	38	35	37	34	40	36	42	36	53	43	62	55	67	64	71	62	72	65	72	66
10	57	53	49	47	41	35	36	34	42	39	42	38	49	44	60	57	71	65	70	61	71	67	72	66
11	59	54	47	44	38	34	37	35	41	38	42	37	48	44	58	55	73	64	71	61	70	67	72	66
12	58	55	46	43	33	33	38	37	39	36	46	40	50	43	57	55	73	66	74	65	72	67	74	67
13	47	52	45	42	33	33	38	35	40	38	41	39	48	39	63	56	76	66	69	67	69	62	72	69
14	59	55	47	44	33	32	43	38	41	38	40	37	51	41	69	59	72	65	71	67	66	58	72	68
15	63	57	52	47	33	33	41	34	41	38	46	39	54	44	67	59	65	61	68	65	68	59	71	62
16	60	58	53	49	35	33	36	34	41	37	45	40	50	46	64	60	69	58	68	64	71	64	65	59
17	59	56	53	48	38	33	38	35	41	37	42	38	52	43	65	55	70	58	71	65	69	62	63	58
18	56	53	48	45	34	33	39	38	41	38	44	37	48	44	62	55	70	59	75	67	70	62	61	55
19	58	52	50	46	33	33	39	36	38	36	40	39	47	43	58	55	70	61	74	67	68	62	53	60
20	58	53	46	43	34	33	36	35	39	36	46	38	55	42	61	54	71	63	70	68	67	64	66	63
21	53	50	46	43	34	32	36	35	40	38	46	39	57	44	61	55	68	65	74	66	65	64	67	64
22	52	47	47	44	33	32	36	35	41	39	45	41	58	51	61	55	65	64	76	67	70	65	68	63
23	50	47	50	46	34	33	36	35	39	38	44	39	62	51	62	54	70	62	75	70	70	66	70	66
24	51	49	48	43	33	32	36	35	42	38	46	40	56	51	64	55	69	63	73	69	68	66	69	64
25	50	49	46	43	35	33	36	35	40	39	48	43	61	51	68	57	68	60	73	68	71	67	69	66
26	51	47	45	41	37	34	36	36	41	39	50	41	66	55	64	57	67	60	73	68	75	68	68	65
27	53	50	46	42	37	34	36	36	44	39	52	44	61	50	57	51	67	63	74	68	71	66	64	59
28	55	53	47	45	34	33	36	35	42	40	55	47	57	51	62	49	71	62	72	67	71	66	64	58
29	56	53	54	47	36	34	36	35	--	--	57	49	53	50	59	55	73	63	72	68	71	65	60	56
30	53	51	52	41	38	36	36	35	--	--	51	47	60	47	60	53	76	66	73	66	70	65	61	53
31	53	62	--	--	37	34	36	36	--	--	49	43	--	--	63	51	--	--	70	67	73	68	--	--

Temperature (°F) of water, water year October 1959 to September 1960

Table 44. - Maximum and minimum daily water temperatures, Pascack Brook at Pearl River, N. Y.

47100

Day	October		November		December		January		February		March		April		May		June		July		August		September	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1							35	34	37	36	38	34	54	47	56	53	65	62	70	66	67	65	71	69
2							36	33	37	35	37	34	52	48	59	50	68	61	69	65	67	66	71	70
3							38	36	35	33	36	33	48	45	61	52	69	65	69	65	68	67	70	66
4							38	37	37	34	34	33	53	44	62	52	68	66	70	67	68	67	66	65
5							37	35	37	36	36	33	52	47	64	55	71	65	68	64	68	66	67	65
6							36	35	38	36	38	34	47	44	64	56	72	67	67	64	68	66	67	65
7							36	35	37	36	37	34	48	42	62	57	68	63	69	64	69	67	68	65
8							37	36	36	33	38	35	46	44	61	69	67	61	69	63	73	68	69	66
9							37	34	39	36	37	34	47	44	59	58	66	61	73	65	71	68	73	68
10							34	34	40	39	38	35	49	43	57	53	66	59	72	67	70	68	69	67
11							34	34	43	39	37	34	50	42	58	54	67	59	71	67	70	68	67	64
12							34	32	42	38	38	34	52	46	60	55	65	63	69	61	69	67	64	64
13							34	32	38	36	40	36	51	46	60	58	67	62	61	60	68	67	65	62
14							34	33	36	33	41	37	55	47	59	56	67	64	65	60	69	67	64	62
15							35	34	34	32	41	36	61	52	59	54	64	63	61	60	71	67	63	60
16					40	38	35	34	37	34	40	37	59	55	64	57	69	62	60	60	70	66	65	62
17					40	38	35	34	38	35	40	37	57	51	64	59	68	65	61	60	68	66	64	62
18					40	40	35	35	40	35	42	38	58	51	63	59	72	67	62	61	69	66	64	63
19					40	38	36	35	38	36	41	38	55	47	66	57	71	65	63	62	68	66	63	63
20					38	36	35	33	38	36	41	37	56	48	64	61	69	66	62	62	67	65	63	62
21					36	36	34	33	37	35	41	37	59	50	65	62	70	65	66	63	68	65	63	61
22					36	35	34	34	37	36	40	36	64	55	64	59	65	64	64	63	72	66	62	61
23					35	33	35	34	38	34	41	35	64	57	59	57	70	65	65	63	68	66	61	59
24					35	33	35	33	38	34	42	38	61	56	62	58	69	67	66	64	67	65	61	59
25					36	35	34	33	37	36	41	36	66	56	62	58	70	66	67	64	66	64	61	60
26					38	36	36	34	38	35	38	36	65	61	66	60	71	64	67	64	67	66	62	60
27					38	38	36	35	38	35	43	36	62	58	67	61	72	64	71	65	67	64	62	60
28					38	37	36	35	37	35	46	42	60	55	64	61	72	65	70	65	69	66	67	61
29					37	35	37	35	39	37	48	42	63	54	62	60	69	67	70	64	71	67	62	62
30					36	35	36	35	--	--	48	46	60	56	61	59	72	66	70	64	72	70	64	62
31					36	35	36	34	--	--	49	46	--	--	65	60	--	--	68	64	71	69	--	--

Temperature (°F) of water, water year October 1960 to September 1961

Table 44. - Maximum and minimum daily water temperatures, Pascack Brook at Pearl River, N. Y. (continued)

47100

Day	October		November		December		January		February		March		April		May		June		July		August		September	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1	63	58	54	51	41	38	35	35	35	35	39	38	47	45	53	49	64	59	74	68	74	71	75	70
2	58	55	53	50	38	37	35	34	35	35	42	38	47	43	54	50	68	62	76	68	71	67	77	72
3	59	57	51	49	40	38	36	35	35	35	45	39	46	42	57	47	68	64	74	70	67	67	76	72
4	58	54	50	48	39	38	36	35	35	35	43	41	49	43	56	48	66	60	70	66	70	67	76	72
5	58	54	49	48	41	38	36	35	35	34	46	42	50	44	61	49	68	61	69	64	70	68	76	72
6	58	56	49	46	41	40	37	36	35	34	45	43	50	45	59	50	70	64	69	64	70	67	74	72
7	56	53	46	44	42	40	39	37	35	34	47	43	50	44	57	53	69	64	68	64	74	68	73	70
8	56	52	44	42	40	37	39	38	35	35	45	38	51	43	58	55	65	61	67	65	73	68	70	68
9	57	53	47	45	37	35	38	35	35	34	41	35	52	43	61	55	64	62	69	63	74	68	70	66
10	58	54	47	45	35	35	36	35	35	35	41	38	49	45	62	58	68	63	70	63	74	70	72	68
11	60	55	45	44	35	34	36	35	36	35	40	35	46	44	60	56	72	64	71	63	73	70	73	68
12	58	56	45	42	34	32	38	36	36	36	44	39	48	43	57	56	73	68	73	66	73	70	73	68
13	56	53	45	43	32	32	38	36	37	36	41	39	47	41	62	56	75	68	70	68	72	67	72	68
14	58	54	47	44	32	32	40	37	37	36	39	37	47	41	59	59	73	67	70	67	68	63	71	69
15	61	57	49	47	32	32	40	35	38	36	43	38	51	43	68	61	67	63	69	66	70	62	71	67
16	62	58	48	33	32	36	36	35	38	36	43	40	49	46	66	62	66	50	70	66	73	66	67	64
17	61	59	51	48	33	32	38	36	38	36	41	36	50	44	65	59	67	59	73	68	70	64	64	62
18	59	56	48	45	33	32	39	38	39	38	42	36	48	45	62	58	68	60	79	69	69	63	62	58
19	56	54	48	46	33	32	38	35	38	36	41	39	46	44	60	56	69	62	74	69	68	63	61	60
20	57	54	46	44	33	33	36	35	38	36	44	38	53	43	60	55	69	63	72	69	67	64	60	60
21	54	51	45	43	34	33	35	35	39	37	46	40	55	45	60	55	67	64	75	69	67	65	60	60
22	51	48	46	44	33	33	35	35	41	38	45	41	58	51	60	56	66	64	77	70	70	65	63	60
23	50	48	48	45	33	33	35	35	39	38	44	38	62	53	60	56	70	64	77	72	70	68	61	61
24	50	48	45	42	33	33	35	35	41	38	43	39	57	53	62	56	69	66	75	72	70	68	61	61
25	48	47	44	42	34	32	35	35	38	36	48	43	60	54	65	58	66	62	77	73	72	69	62	61
26	49	46	44	41	34	34	35	35	38	36	50	43	65	57	64	59	68	62	76	72	74	71	62	62
27	50	48	45	41	36	35	35	35	42	37	52	46	61	52	59	52	66	64	76	72	75	72	62	61
28	52	50	47	45	35	34	35	35	40	39	55	49	58	52	60	50	68	63	75	70	75	70	61	60
29	52	50	50	46	34	34	35	34	--	33	56	41	54	51	59	56	72	64	73	70	74	70	61	59
30	52	50	49	41	35	34	35	35	--	--	53	48	58	48	59	54	74	67	75	68	73	68	59	57
31	51	51	--	--	36	34	35	35	--	--	49	45	--	--	62	53	--	--	74	71	74	69	--	--

Table 45. - Monthly and annual runoff, Sparkill Creek Basin, 1960, 1961 water years

1960 Water Year

	Drain-age Area	cfs/sq. mi.												
		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Year
At Tappan	4.94	1.17	1.71	2.27	1.96	3.22	1.56	2.51	1.61	.785	1.12	2.00	2.37	1.85
Int. Area	6.19	8.61 1.39	12.2 1.97	18.2 2.94	13.9 2.25	23.4 3.78	12.1 1.95	15.2 2.46	8.69 1.40	5.63 .910	7.35 1.19	10.4 1.68	16.0 2.58	12.6 2.04
At Sparkill	11.1	1.30	1.86	2.65	2.12	3.54	1.77	2.49	1.50	.857	1.16	1.83	2.50	1.95

1961 Water Year

At Tappan	4.94	0.773	1.20	1.08	1.31	3.58	3.08	3.44	1.44	.567	1.43	1.10	.563	1.62
Int. Area	6.19	6.15 0.994	8.36 1.35	8.00 1.29	10.1 1.63	25.1 4.05	22.5 3.63	24.7 3.99	8.56 1.38	5.09 .822	8.50 1.37	9.81 1.58	3.70 .598	11.6 1.87
At Sparkill	11.1	0.898	1.29	1.21	1.50	3.86	3.41	3.75	1.41	.712	1.41	1.37	.584	1.77

Note: Flow includes sewage effluent above Tappan and also additional effluent between Tappan and Sparkill.

Table 46. - Monthly and annual runoff, Hackensack River Basin, 1960

		1960 Water Year												
	Drainage Area	cfs/sq. mi.												
		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Year
At Brookside Park	13.2	1.32	1.52	2.91	2.49	3.61	1.86	2.87	1.41	0.848	1.48	1.97	2.57	2.06
Int. Area	16.2													
At West Nyack	29.4	1.35	.701	2.91	2.43	4.15	1.63	3.07	1.27	.803	1.23	1.66	2.20	1.94
Nauraushaun Br.	6.08	--	--	--	--	4.90	1.73	3.22	1.23	.382	1.44	2.20	2.50	--
Int. Area	9.41													
Hackensack River at Nauraushaun	44.9	--	--	2.90	2.43	3.70	1.70	2.76	1.27	.604	1.18	1.81	2.20	--
Int. Area	13.1	--	--	0.692	1.98	1.94	1.06	1.51	1.20	0.634	1.34	1.74	1.84	--
Hackensack River at Rivervale, N. J.	58.0	1.35	1.07	2.40	2.33	3.29	1.56	2.47	1.26	0.610	1.22	1.79	2.12	1.78

Table 47. - Monthly and annual runoff, Pascack Brook Basin, 1960, 1961 water years

1960 Water Year

	Drainage Area	cfs/sq. mi.												
		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Year
Pascack Brook Tributary	4.58	0.954	.959	1.89	1.87	2.55	1.61	2.71	1.28	.762	1.62	1.98	2.25	1.70
Int. Area	5.63	1.25	1.12	2.18	2.03	3.07	1.39	2.49	1.13	.440	1.30	2.14	2.50	1.74
Pascack Brook[a]	10.2	1.36	1.29	2.29	2.21	3.09	1.74	2.83	1.44	.830	1.69	2.31	2.64	1.97

[a] Includes about 2.5 cfs sewage effluent.

1961 Water Year

	Drainage Area	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Year
Pascack Brook Tributary	4.58	1.26	.963	.797	.856	2.58	3.54	3.43	2.27	.954	1.18	.793	.620	1.60
Int. Area	5.63	0.856	1.28	.826	1.24	3.64	4.80	4.33	2.02	1.18	1.44	.794	.917	1.93
Pascack Brook[a]	10.2	1.28	1.38	1.06	1.31	3.41	4.48	4.18	2.38	1.32	1.57	1.04	1.03	2.03

[a] Includes about 2.5 cfs effluent from Spring Valley.

Table 48. - Monthly and annual runoff, Mahwah River Basin, 1959-61 water years

	Drainage Area	cfs/sq. mi.												
		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Year
1959 Water Year														
Near Suffern	12.3	2.09	1.96	1.83	1.20	1.59	3.07	2.71	1.12	0.654	0.289	0.450	0.201	1.43
Int. Area	8.32	--	--	--	--	--	--	--	--	--	--	6.53 0.785	3.53 .424	--
At Suffern	20.7	--	--	--	--	--	--	--	--	--	--	0.585	.290	--
1960 Water Year														
Near Suffern	12.3	1.23	1.99	3.37	2.77	3.80	2.20	4.05	1.90	.810	1.15	2.59	2.60	2.37
Int. Area	8.32	10.2 1.23	13.7 1.65	22.9 2.75	22.8 2.74	27.8 3.34	18.4 2.21	28.1 3.38	17.5 2.10	8.96 1.08	9.01 1.08	17.0 2.04	21.9 2.63	18.2 2.19
At Suffern	20.7	1.22	1.85	3.11	2.75	3.60	2.19	3.77	1.98	.913	1.13	2.36	2.61	2.28
1961 Water Year														
Near Suffern	12.3	1.24	1.48	1.46	1.50	4.38	5.43	5.11	2.68	1.16	.837	.653	.383	2.18
Int. Area	8.32	11.5 1.38	10.0 1.20	9.61 1.16	11.3 1.36	22.4 2.69	39.7 4.77	33.7 4.05	22.7 2.73	9.20 1.11	6.87 .826	4.28 .514	2.75 .331	15.3 1.84
At Suffern	20.7	1.29	1.36	1.33	1.44	3.69	5.17	4.66	2.69	1.14	.826	.549	.361	2.03

Table 49. - Monthly and annual runoff, Ramapo River Basin, 1960

	1960 Water Year												
	Drainage Area	cfs/sq. mi.											
		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Year
Ramapo River at Sloatsburg	60.9	1.61	2.43	3.20	2.66	3.46	1.94	4.50	1.30	1.06	1.79	4.38	3.71	2.66
Stony Brook at Sloatsburg	18.2	3.27	.659	1.48	3.15	3.90	2.16	4.37	1.48	.797	1.84	3.98	4.40	2.62
Mahwah River at Suffern	20.7	1.22	1.85	3.11	2.75	3.60	2.19	3.77	1.98	.913	1.13	2.36	2.61	2.28
Int. Area	18.2	24.5 1.35	32.6 1.79	70.2 3.86	49.1 2.70	57.7 3.17	34.5 1.90	90.1 4.95	37.7 2.07	21.8 1.20	23.2 1.27	37.7 2.07	37.7 2.07	42.9 2.36
Ramapo River at Mahwah, N. J.	118	1.76	1.95	3.03	2.75	3.51	2.01	4.42	1.57	1.02	1.59	3.61	3.36	2.54

Table 50. - List of miscellaneous measurements

Discharge measurements made at points other than gaging stations in Rockland County

Stream	Tributary to	Location	Drainage Area (sq. mi.)	Date	Discharge (cfs)
		Hudson River basin			
Lake Tiorati Brook	Cedar Pond Brook	Lat 41°14'55", long 74°02'35", at bridge on Palisades Interstate Parkway, 300 ft upstream from Stillwater Brook, 1 mile northwest of Cedar Flats	5.17	9-27-60 9-27-61	9.92 1.29
Stillwater Brook	Lake Tiorati Brook	Lat 41°15'00", long 74°02'31", 30 ft upstream from Lake Tiorati Brook, 1 mile northwest of Cedar Flats	3.56	9-27-60 9-27-61	5.77 .49
Jackie Pond Outlet	do.	Lat 41°14'31", long 74°01'37", just upstream from mouth at Cedar Flats	.08	10-14-59 9-27-61	.21 .01
Pound Swamp Creek	do.	Lat 41°14'27", long 74°01'36", 250 ft upstream from mouth at Cedar Flats	1.16	10-14-59 9-27-61	.55 .20
Pingyp Brook	Cedar Pond Brook	Lat 41°14'18", long 74°01'20", at bridge on State Highway 210, just upstream from mouth, 0.3 mile east of Cedar Flats	.33	6-23-60 9-27-60 9-27-61	.04 .64 .03
Ambreys Pond Outlet	do.	Lat 41°14'12", long 74°00'28", at bridge on State Highway 210, just upstream from mouth at Stony Point	3.43	4-25-60 9-27-60 9-27-61	3.52 5.54 .80

Table 50. - List of miscellaneous measurements (continued)

Discharge measurements made at points other than gaging stations in Rockland County

Stream	Tributary to	Location	Drainage Area (sq. mi.)	Date	Discharge (cfs)
Cedar Pond Brook Tributary	Cedar Pond Brook	Hudson River basin (continued) Lat $41^{\circ}13'58''$, long $74^{\circ}15'14''$, just upstream from mouth, 50 ft upstream from Goetschius Brook, about 0.1 mile upstream from Stony Point Reservoir, at Stony Point	.03	6-23-60 9-27-60 9-27-61	0.03 .07 .02
Goetschius Brook	do.	Lat $41^{\circ}13'53''$, long $74^{\circ}07'41''$, just upstream from mouth at Stony Point	.41	6-23-60 9-27-60 9-27-61	.26 1.23 .27
Sparkill Creek	Hudson River	Lat $41^{\circ}01'56''$, long $73^{\circ}56'32''$, at Palisades Interstate Parkway, 0.7 mile upstream from gaging station at Tappan	4.21	7-26-60 9-26-60 10-14-60 9-26-61	1.23 3.17 1.97 1.75
Sparkill Creek Tributary	Sparkill Creek	Lat $41^{\circ}01'34''$, long $73^{\circ}56'55''$, at mouth 1,000 ft upstream from gaging station at Tappan	0.49	7-26-60 9-26-60 10-14-60 9-26-61	.03 .12 .06 .05
Sparkill Creek	Hudson River	Lat $41^{\circ}01'44''$, long $73^{\circ}55'58''$, at Palisades Interstate Parkway, 0.4 mile northeast of Tappan Station, and 0.7 mile upstream from Sparkill gaging station	10.6	9-26-60 10-14-60 9-26-61	8.52 5.30 4.80
Hackensack River	Atlantic Ocean	Hackensack River basin Lat $41^{\circ}10'58''$, long $74^{\circ}00'16''$, at culvert on Little Tor Road, 0.3 mile upstream from Lake Lucille, 2 miles south of West Haverstraw	2.18	12-8-59 4-5-60 7-26-60 9-27-60 10-14-60 9-26-61	5.55 38.6 .60 2.37 1.33 .64

Table 50. - List of miscellaneous measurements (continued)

Discharge measurements made at points other than gaging stations in Rockland County

Stream	Tributary to	Location	Drainage Area (sq. mi.)	Date	Discharge (cfs)
		Hackensack River basin (continued)			
New City Brook	Hackensack River	Lat 41°08'55", long 73°59'25", at bridge on State Highway 304 at New City	2.39	6-23-60 7-25-60 9-26-60 10-14-60 9-26-61	2.13 1.53 3.16 2.39 1.77
Nauraushaun Brook	do.	Lat 41°05'46", long 74°00'40", at bridge on State Highway 59, at Nanuet	2.33	7-25-60 9-26-60 10-14-60 9-26-61	.53 1.78 1.09 .97
Nauraushaun Brook Tributary	Nauraushaun Brook	Lat 41°05'23", long 74°00'15", at bridge on Church Street at Nanuet	.83	11-9-60	.27
Pascack Brook	Hackensack River	Lat 41°06'22", long 74°01'56", at railroad bridge just upstream from sewage disposal outfall 600 ft north of State Highway 59 at Spring Valley	2.32	6-22-60 7-26-60 9-26-60 10-14-60 9-26-61	.45 .08 1.38 .54 .56
		Passaic River basin			
Cranberry Pond Outlet	Tributary to Ramapo River	Lat 41°09'14", long 74°11'40", just upstream from unnamed tributary, 50 ft upstream from partial-record station, 150 ft upstream from State Highway 17, at Sloatsburg	3.43	8-6-59 10-26-59 3-21-60 3-31-60 4-1-60 4-4-60 9-28-60 9-21-61	1.40 5.91 4.17 27.6 26.2 32.4 5.07 1.83

Table 50. - List of miscellaneous measurements (continued)

Discharge measurements made at points other than gaging stations in Rockland County

Stream	Tributary to	Location	Drainage Area (sq. mi.)	Date	Discharge (cfs)
		Passaic River basin (continued)			
Mahwah River Tributary	Mahwah River	Lat 41°08'18", long 74°06'45", at bridge on Viola Road, 0.4 mile east of U. S. Highway 202, 2 miles northeast of Suffern	1.04	12-17-59 4-25-60 9-27-60 9-27-61	2.54 2.61 1.81 .67
Mahwah River Tributary No. 2	do.	Lat 41°07'28", long 74°08'00", at bridge on Montebello Road, 0.1 mile upstream from mouth 0.8 mile northeast of Suffern	2.21	12-17-59 4-25-60 9-27-60 9-27-61	3.82 4.23 2.02 .28